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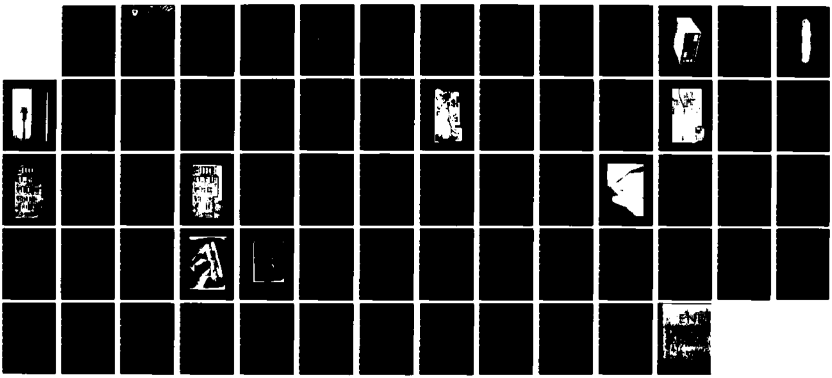

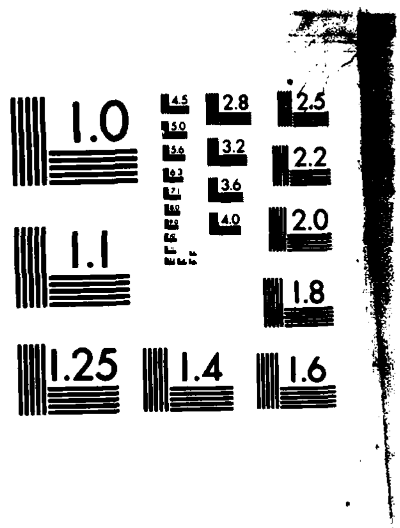


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REPORT CECOM-81-C-0077-F

RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CECOM

# FINAL TECHNICAL REPORT ON BIDIRECTIONAL FIBER OPTIC CABLE ADAPTER

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February 1983

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The technical objective of the BIFOCS program was to develop, build, and test a full-duplex single fiber, fiber optic link, operating in the 1.0 μm to 1.6 μm region, capable of transmitting 20 Mb/s data ($10^{-9}$ BER) over a range of at least 10 km, with a goal of 15 km. The link MTBF goal was 5 X $10^3$ hours and operation over a temperature range of 0°C to 50°C. The fiber optic cable consisted of sections not exceeding 2 km in length joined by commercially available dry fiber optic connectors. The system performed successfully at ambient temperature over 15 km of cable.


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## 1.1 TECHNICAL REQUIREMENTS

The technical objective of the BIFOCS program was to develop, build, and test a full-duplex single fiber, fiber optic link, operating in the 1.0 $\mu m$ to 1.6 $\mu m$ region, capable of transmitting 20 Mb/s data ($10^{-9}$ BER) over a range of at least 10 km, with a goal of 15 km. The link MTBF goal is 5 X $10^3$ hours and it must operate over a temperature range of $0^oC$ to $50^oC$. The fiber optic cable must consist of sections not exceeding 2 km in length joined by commercially available dry fiber optic connectors.

## 2.1 BIFOCS SYSTEM

### 2.1.1 System Description

The BIFOCS System is an exploratory development model of a long-wavelength, optically multiplexed, full-duplex 20 Mb/s transmission system developed for CECOM by GTE Products Corporation (CSD) under Contract DAAK80-81-C-0077. It was developed in accordance with the requirements of CECOM Specification No. 21-81 dated 10 June 1980 entitled "Bi-Directional Fiber Optic Cable Adapter"

The function of BIFOCS is the simultaneous transmission of two different wavelengths of light in opposite directions over a single optical fiber. The system consists of two modem terminals (see Figure 1) and nine cable assemblies. These modems differ from each other only in the emitted wave length of the diode laser used in each and the connection configuration of the duplexer ports to the electro-optical components (see Figure 2). The cable assemblies, consisting of a single-fiber optical cable connectorized with prototype (plastic, commercial grade) GTE expanded beam connectors (see Figure 3). These cables total 15 km in length as shown in Section 2.1.3.

The prototype GTE connector was designed and fabricated by GTE Connector Products Operation to provide a backshell function for the GTE developed expanded beam microlens (Figure 4). The backshell

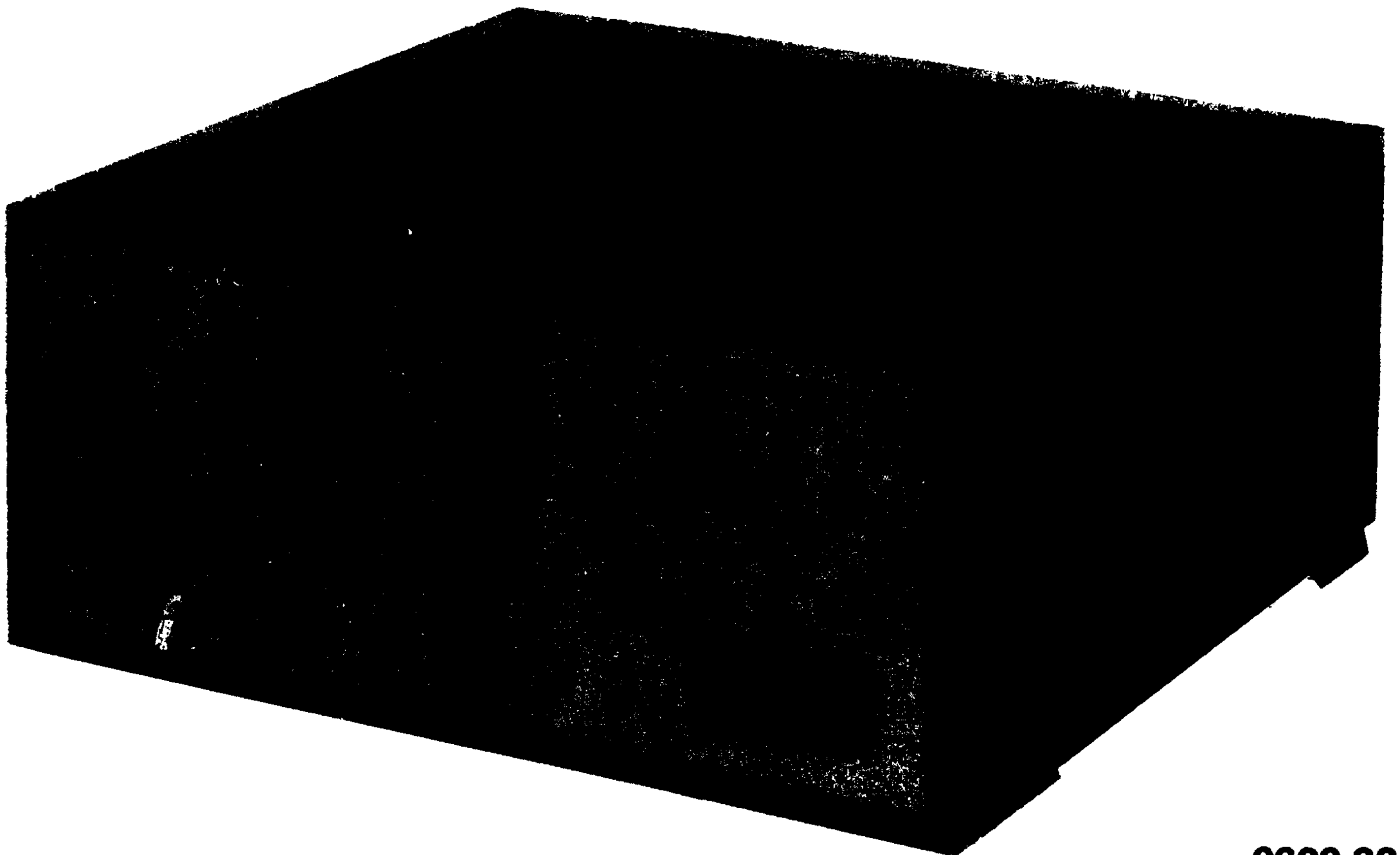

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Figure 1. BIFOCS Terminal (Modem)

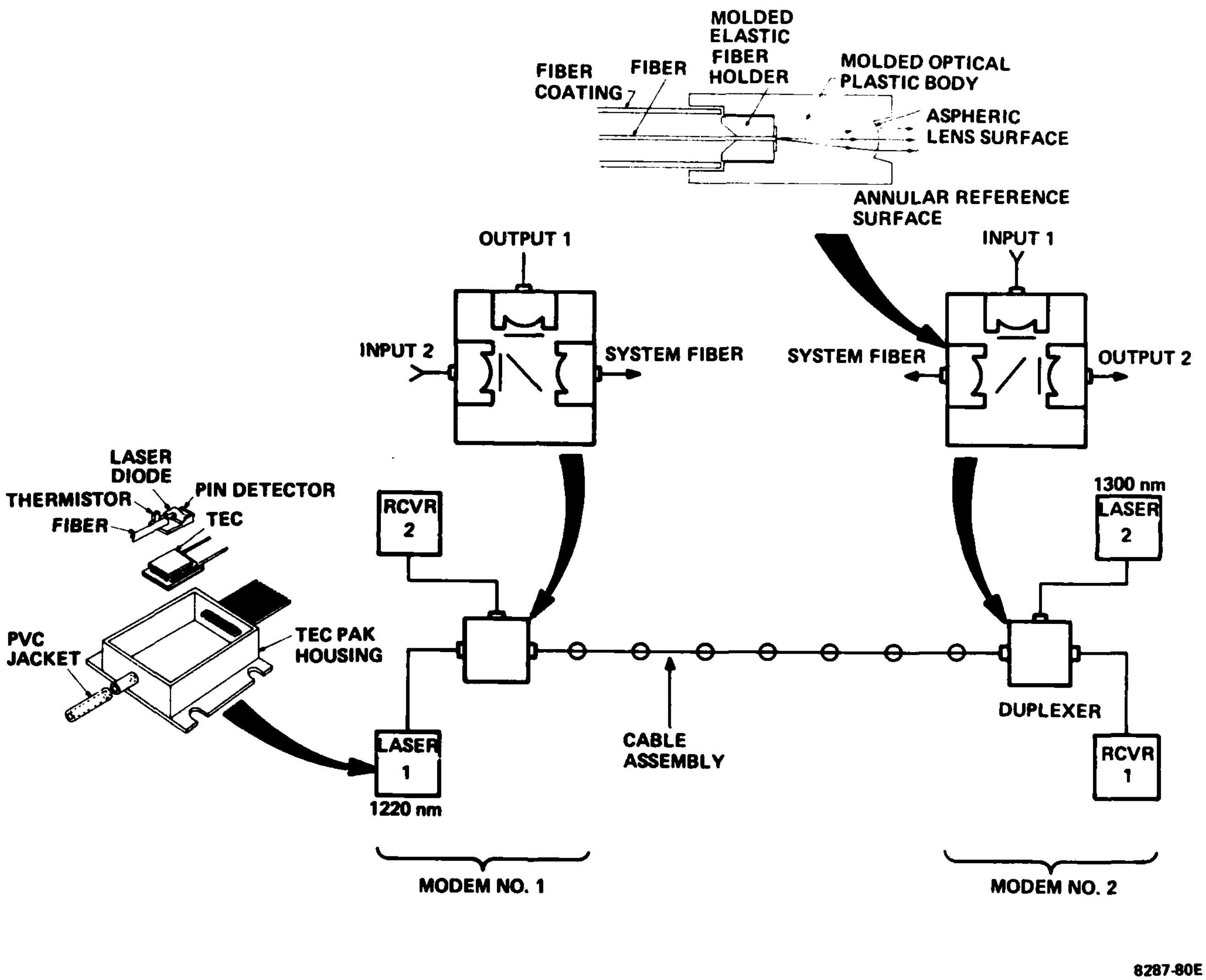


Figure 2. BIFOCS System Configuration

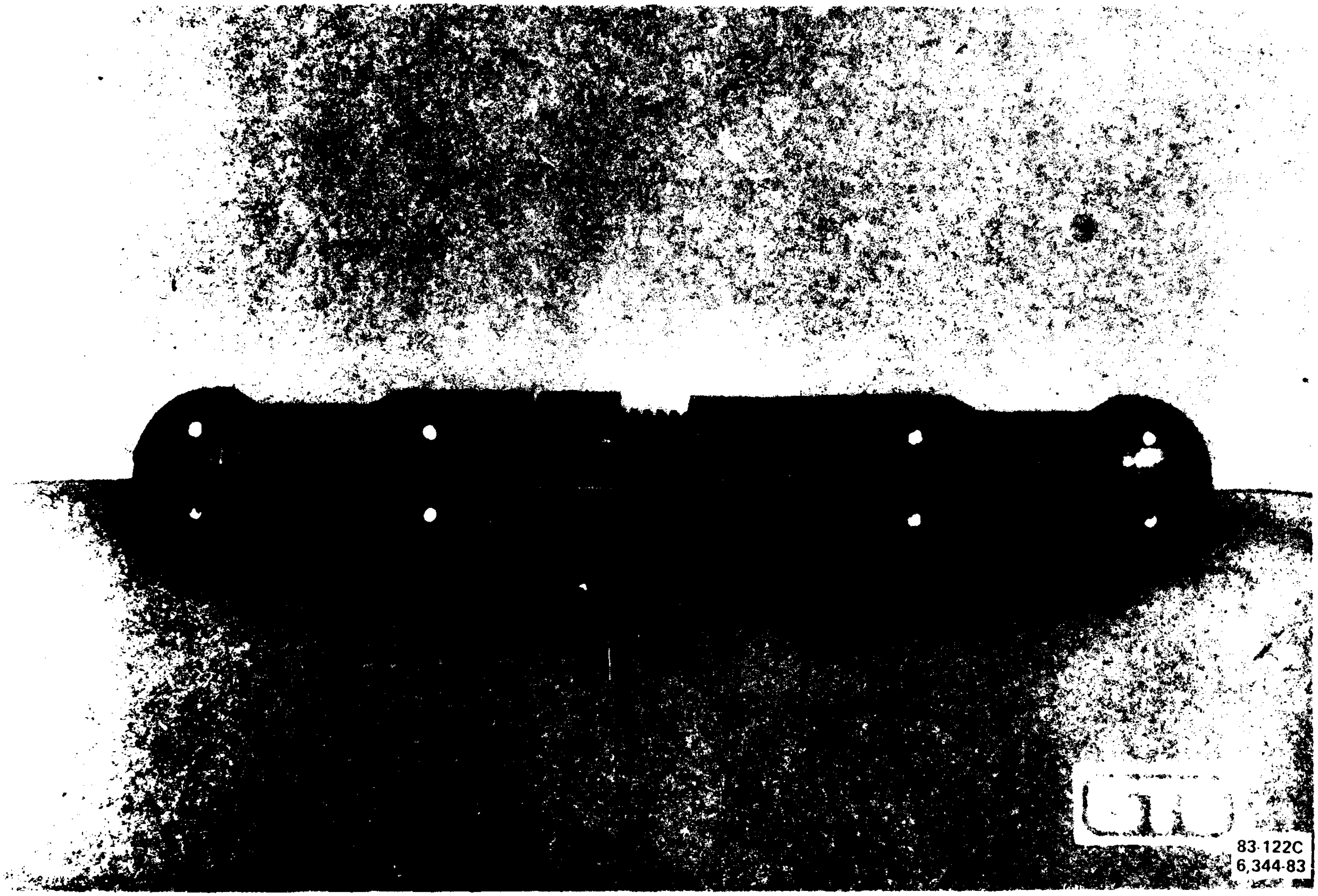


Figure 3. Optical Expanded Beam Connector

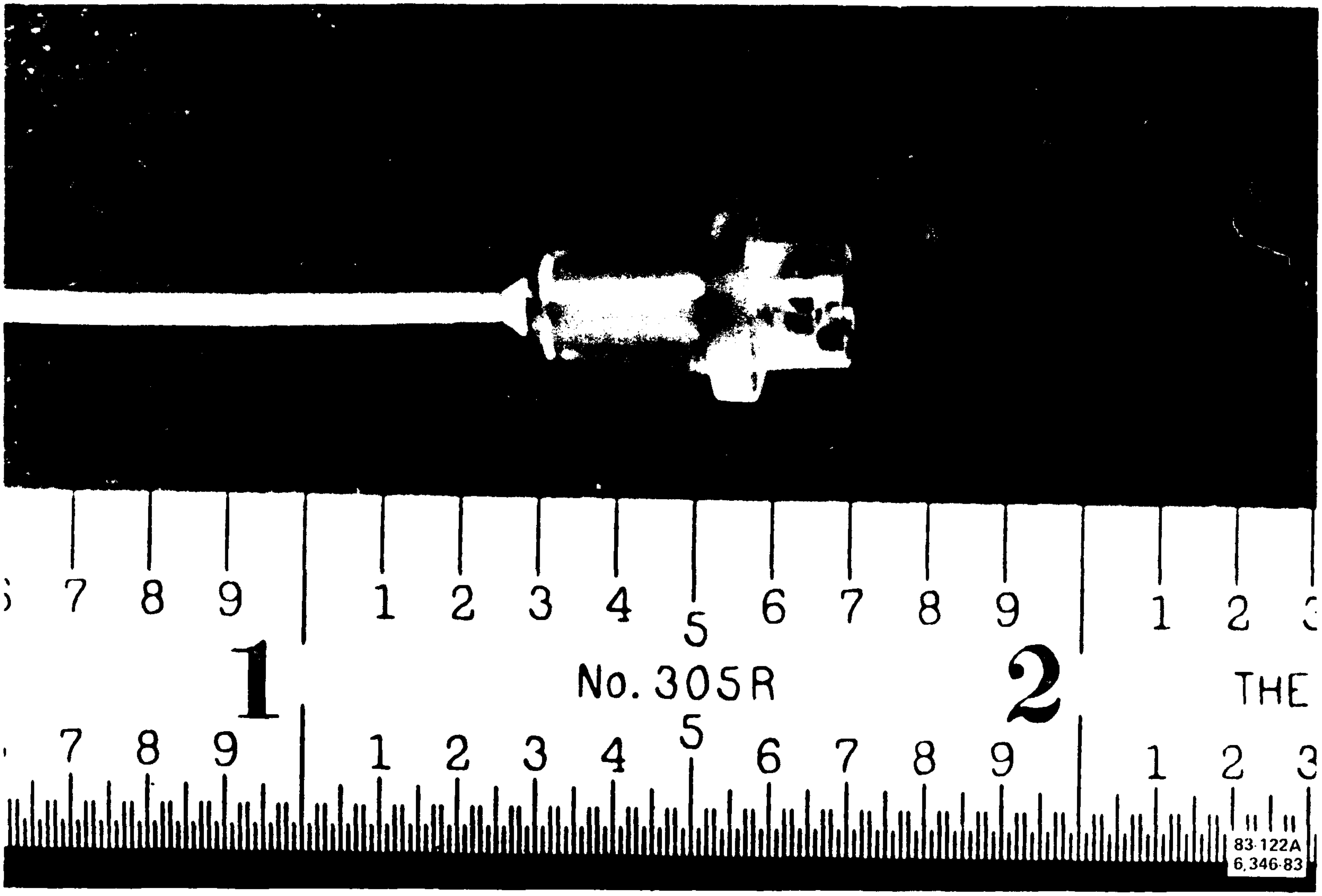


Figure 4. Microlens with Inch Scale and Installed Fiber

provided coarse axial alignment and a means to press the annular alignment surfaces of the microlens pair together. The connector also provides for limited strain relief of the cable.

### 2.1.2 System Operation

During actual operation, digital data at 20 Mb/s and a clock signal of 20 MHz are applied to the encoder via the Coder/Decoder (CODEC) card. Here the data is converted to Manchester format which is then sent to the transmitter. The transmitter performs a conversion of digital to optical signals and is capable of transmission at one wavelength, either 1.2 μm or 1.3 μm. The optical signal is then sent to the duplexer where it is directed out to the optical transmission cable.

Through a beamsplitter arrangement, the duplexer directs incoming optical signals to the receiver which converts the optical signal to

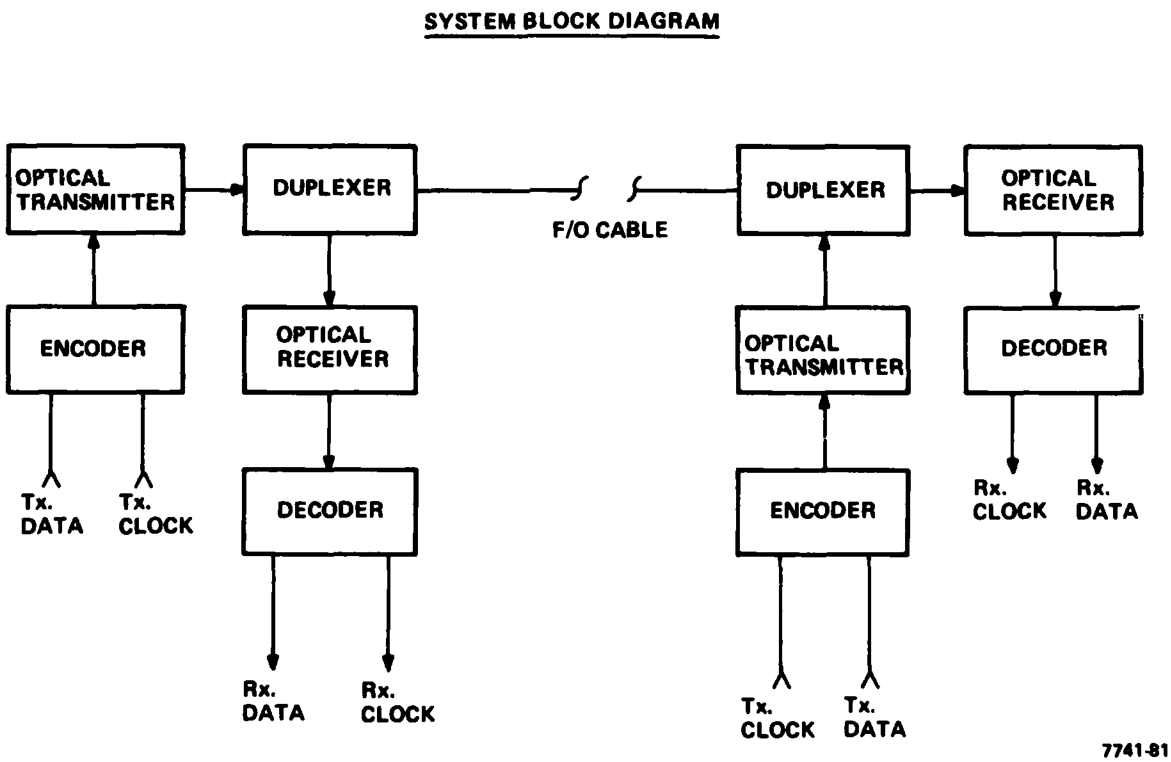


Figure 5. System Block Diagram

an electrical signal in Manchester format. This signal is then converted by the decoder back into a normal digital signal. Correct operation requires a matched pair of duplexers, one transmitting at 1.2 μm and receiving at 1.3 μm and a second unit transmitting at 1.3 μm and receiving at 1.2 μm (See Figure 5, System Block Diagram).

### 2.1.3 System Performance Specifications

The system is capable of simultaneous operation of data at 20 Mb/s, NRZ, under the following conditions:

Distance . . . . . . . . 10 km minimum, 15 km goal

BER . . . . . . . . . . $10^{-9}$

Interface . . . . . . . . TTL (data and clock)

Temperature Range . . $0^{o}C$ to $50^{o}C$

MTBF (Source). . . . . . $10^4$ hours (estimated) minimum

MTBF (System). . . . . . 5 X $10^3$ hours target

Power . . . . . . . . . 115 Vac

Cable Plant . . . . . . 1 to 2 km connectorized single fiber cable assemblies (Qty 4 of 1 km nominal length, Qty 5 of 2 km nominal length, with 15.3 km total) (see Table 1 for specific lengths)

TABLE 1. CABLE ASSEMBLIES

| ID Number | Length (Meters) | ID Number | Length (Meters) |
|---|---|---|---|
| 1 | 2222 | 6 | 1046 |
| 2 | 2180 | 7 | 1085 |
| 3 | 2225 | 8 | 1131 |
| 4 | 2230 | 9 | 137 |
| 5 | 2015 | | |

## 3.1 MAJOR HARDWARE FUNCTIONS

Each modem consists of five major functional units and associated power supplies, indicators and controls. See Table 2.

TABLE 2. MAJOR FUNCTIONAL UNITS

| Unit | Location | Function |
|---|---|---|
| Transmitter | On Transmitter Card | Converts encoded data to optical signal |
| Receiver | On Receiver Card | Converts optical signal to electrical signal |
| Encoder | On CODEC Card | Codes input data into Manchester format |
| Decoder | On CODEC Card | Decodes Manchester data to NRZ, TTL data |
| Duplexer | Located Mid-Chassis | Provides optical mixing/ separation function |

### 3.1.1 Fiber Optic Transmitter

#### 3.1.1.1 Description

The fiber optic transmitter (see Figure 6) accepts data from the encoder and converts the electrical pulses into optical pulses by means of a solid-state laser operating in the 1.20 μm to 1.35 μm wavelength range. The specific wavelength of operation is critical and must be matched to the duplexer connectivity of the particular modem terminal and the wavelength of the terminal at the other end of the link (see Figure 7). The transmitter card (see Figures 8 & 9) includes circuits to set the bias current of the laser, to adjust the bias current by sensing the average optical power output of the laser, and to sense and regulate the temperature of the laser package's thermoelectric cooler in order to stabilize output wavelength and maximize device reliability. The parts list for the transmitter (PN06-1371757-1) is given in Appendix A.

#### 3.1.1.2 Performance Specifications

The transmitter must operate over the voltage and frequency ranges of the expected input (encoder output) bit stream at all points within the operating temperature range. These ranges are:

Logic "0" . . . . 0.2 V to 0.4 V
Logic "1" . . . . 2.4 V to 2.7 V
Frequency . . . . 20 Mb/s ± 5% (Manchester)
Temperature . . . $0^{\circ}C$ to $50^{\circ}C$

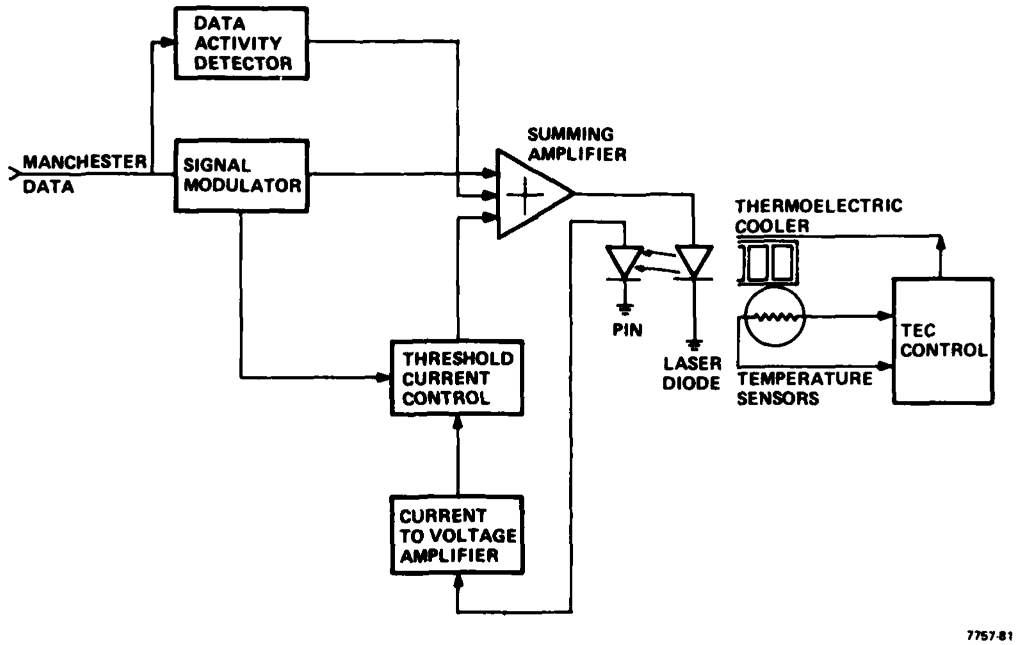


Figure 6. Optical Transmitter Block Diagram

### 3.1.1.3 Acceptance Limits

The transmitter shall exhibit the minimum performance as shown below at 20°C and 50°C when driven by an input signal within the ranges shown above.

Output Power . . . . . . 1 milliwatt average, optical minimum

Wavelength . . . . . . . 1.21 μm $\pm 0.01$

OR

1.31 μm $^{+\,0.02}_{-\,0.00}$ μm

Extinction Ratio . . . . 12:1 minimum

The power requirement is derived from the link power budget analysis (Section 3.3.4, Table 3) and the wavelengths and tolerances

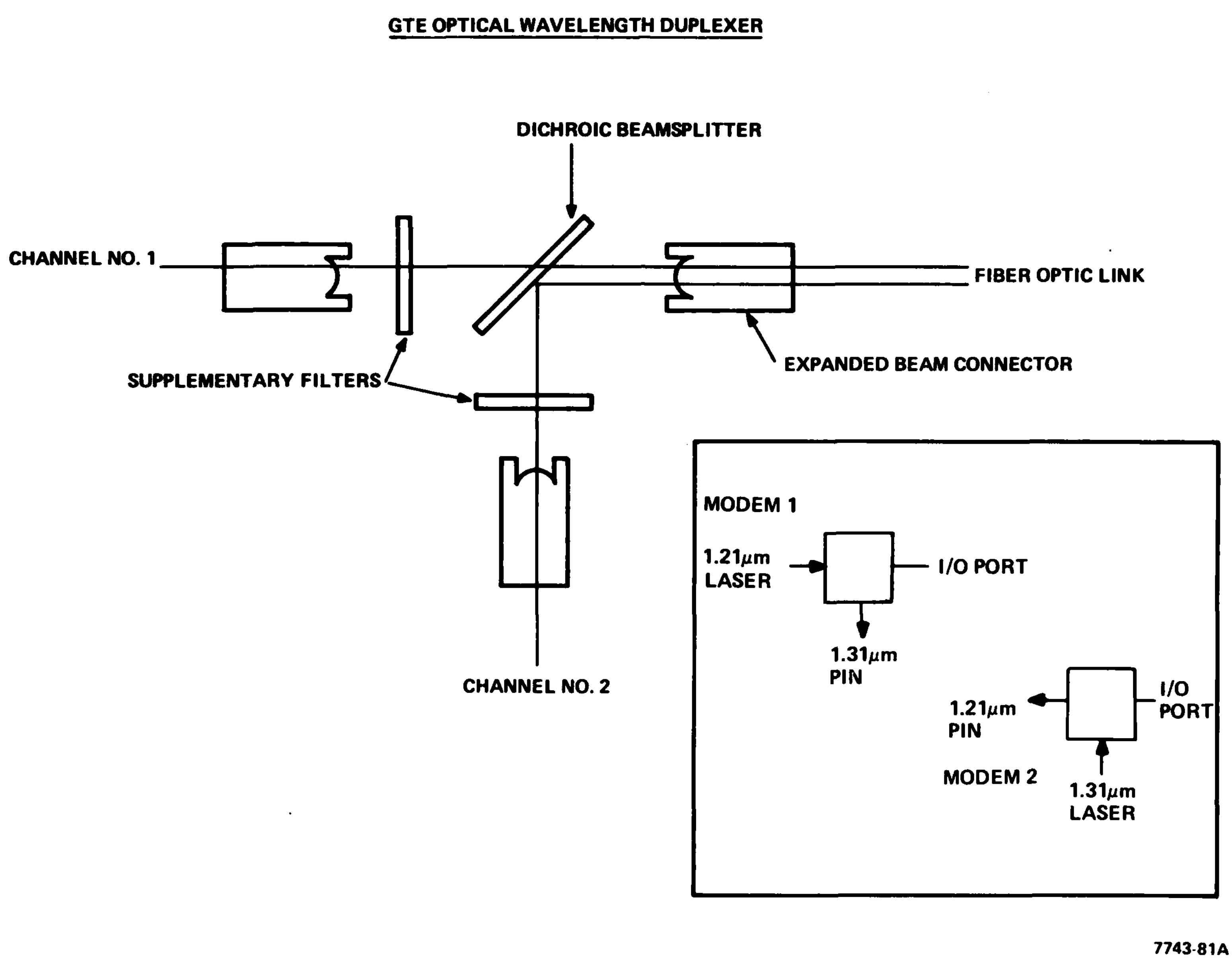


Figure 7. Modem Configuration Difference

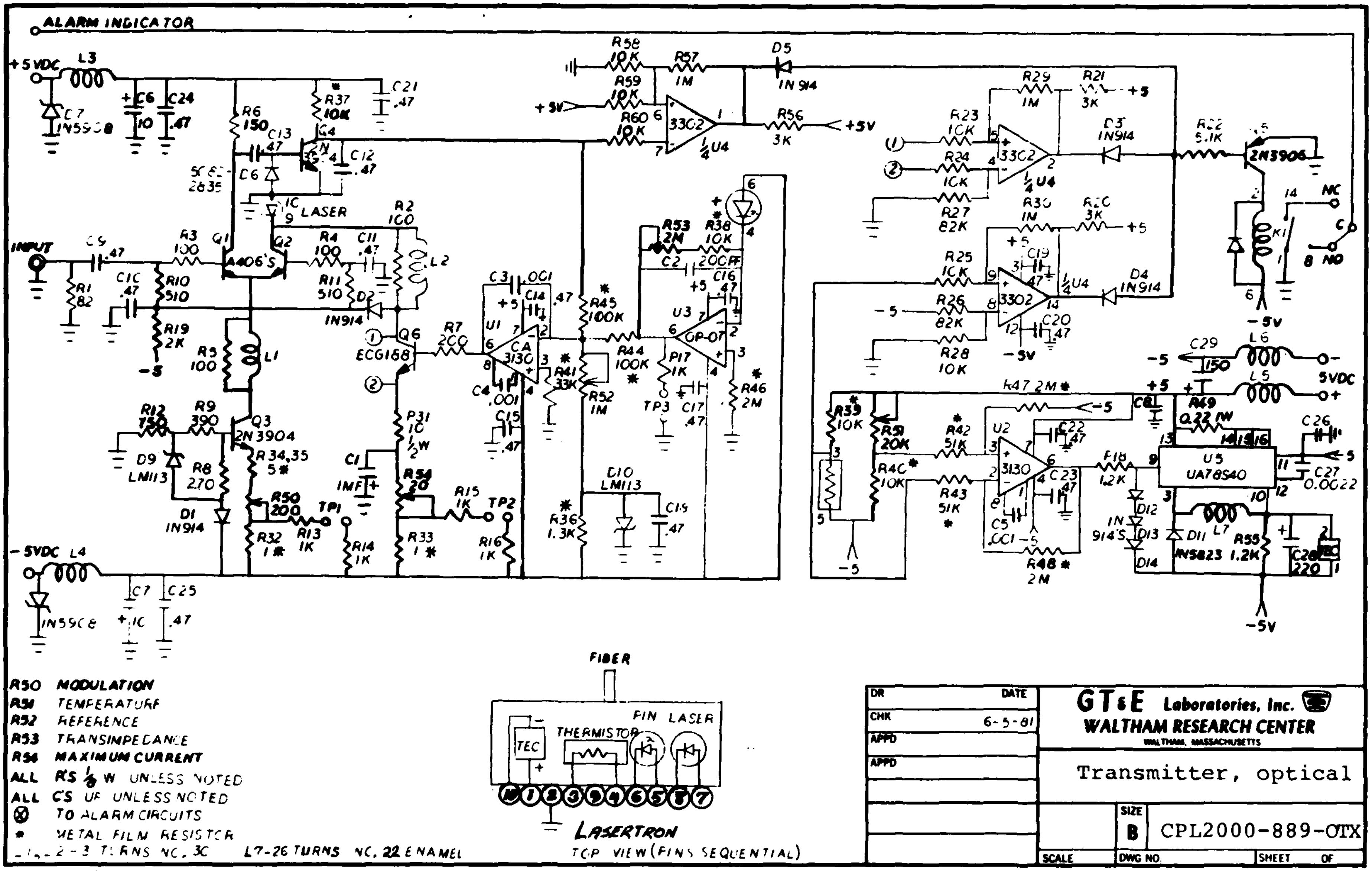


Figure 8. Transmitter Schematic

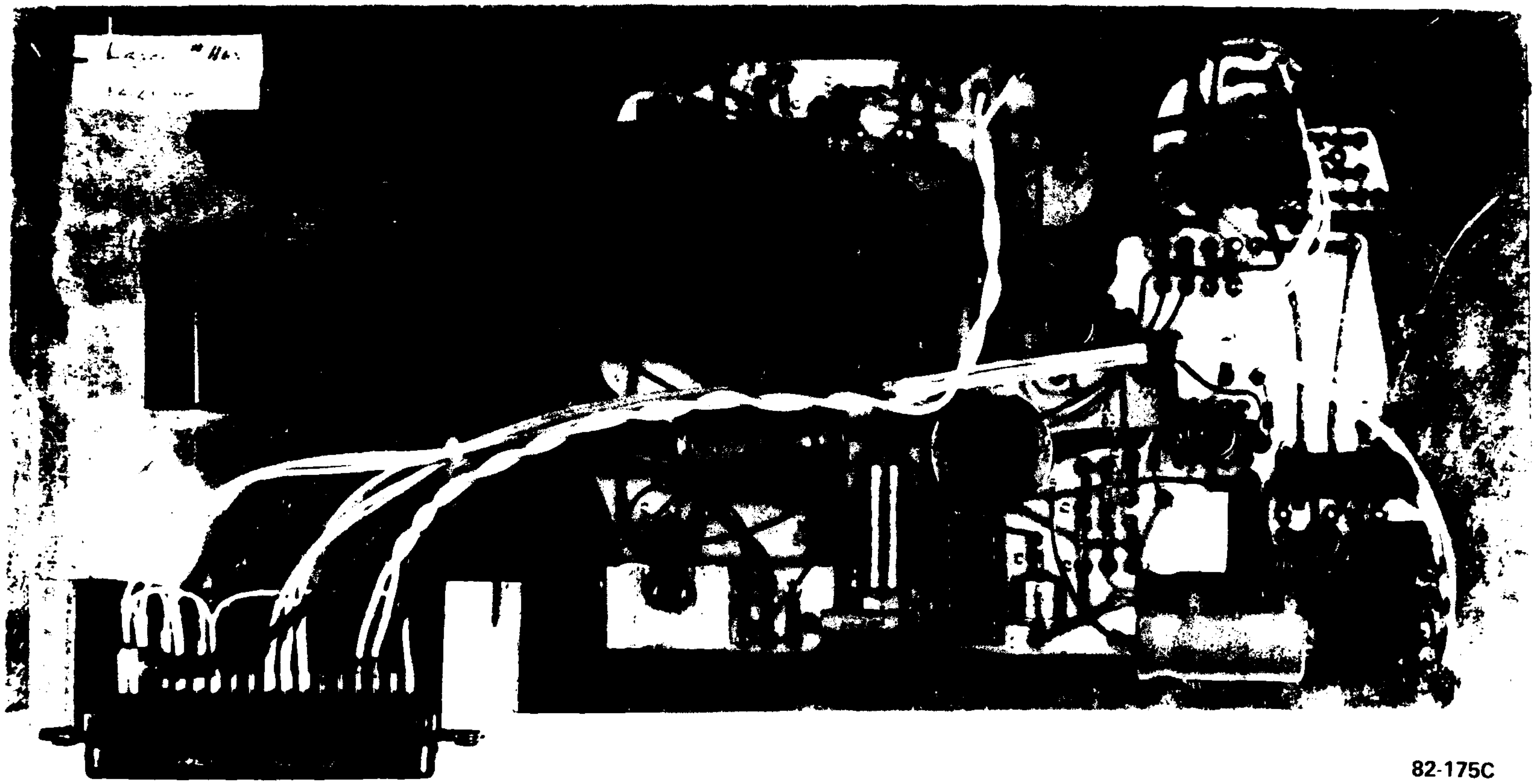

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Figure 9. Transmitter Card

from the crosstalk analysis (Section 3.3.4, Table 4) and the duplexer characteristic (Section 3.3.4, Tables 5 and 6).

### 3.1.2 Fiber Optic Receiver

#### 3.1.2.1 Description

The fiber optic receiver (see Figures 10, 11 and 12) converts optical pulse inputs into electrical signals and amplifies them to a TTL voltage level before applying them to the decoder. The optical to electrical conversion is accomplished by a PIN diode, followed by a low noise, high gain transimpedance amplifier. The transimpedance amplifier is followed by several subsequent gain stages. These gain stages are controlled by automatic gain control (AGC) circuits, which allow the receiver to adjust to a wide range of input optical power levels. The signal provided to the decoder is basically an analog electrical representation of the received optical signal.

The parts list for the receiver (PN 06-1371759-1) is given in Appendix A.

#### 3.1.2.2 Performance Specifications

The receiver must operate over a temperature range of $0^{\circ}C$ to $50^{\circ}C$, with average input optical power levels of -45 dBm to -25 dBm, at a frequency of 20 Mb/s (Manchester), for any wavelength in the 1.20 μm to 1.35 μm range. The average optical input power is to be determined by measurement using a calibrated photometer with adjustment for the specific wavelength being measured.

#### 3.1.2.3 Acceptance Limits

The receiver shall have an electrical output (0.2 V to 0.4 V for "0" state, 2.4 V to 2.7 V for the "1" state) representative of the optical input bit pattern for any optical input signal with a wavelength between 1.20  m and 1.35  m and a power (average) of -45 dBm to -25 dBm, at a nominal 20 Mb/s (± 5%) data rate (Manchester) over a $0^{\circ}C$ to $50^{\circ}C$ temperature range.

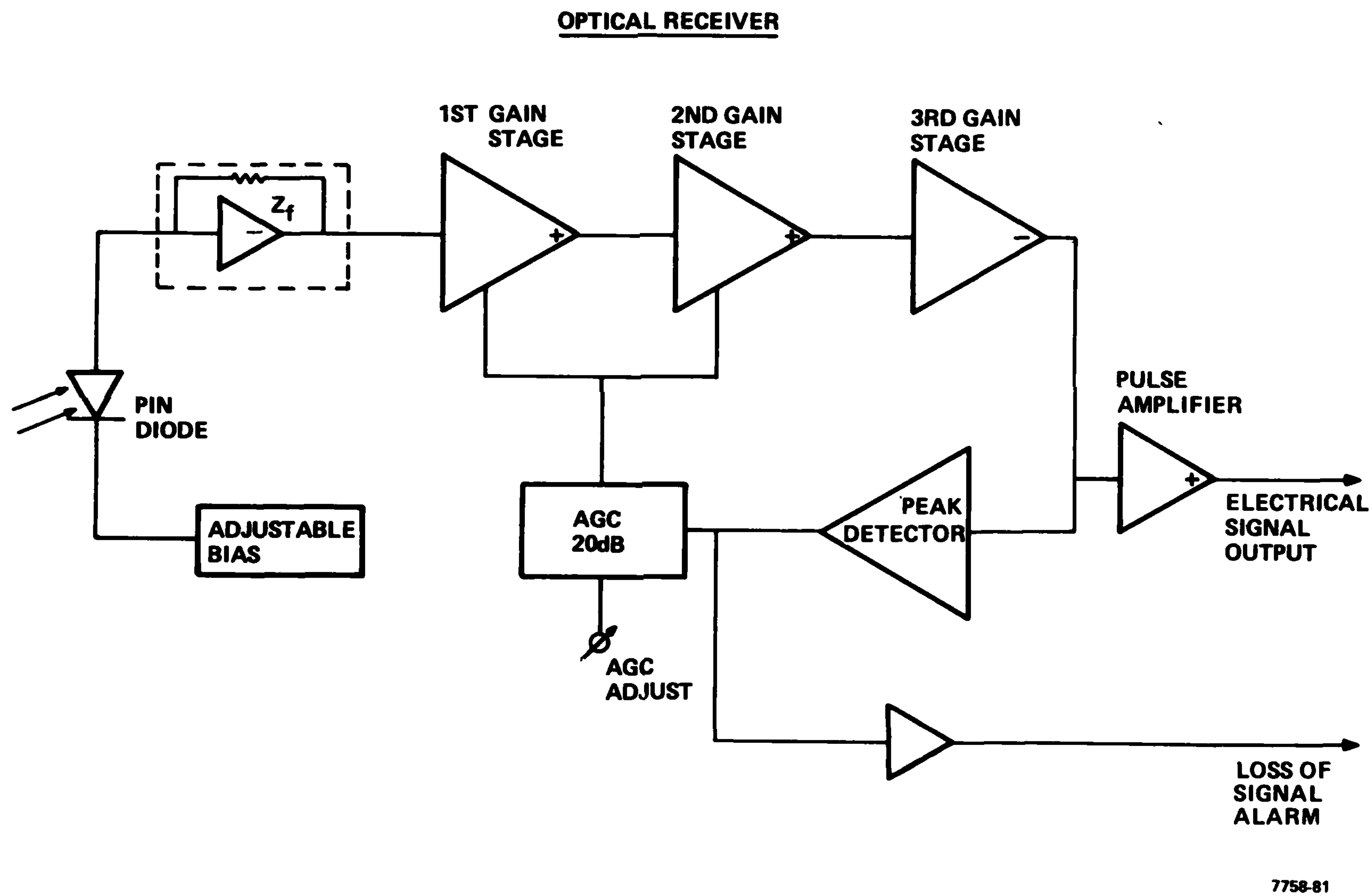


Figure 10. Optical Receiver Block Diagram

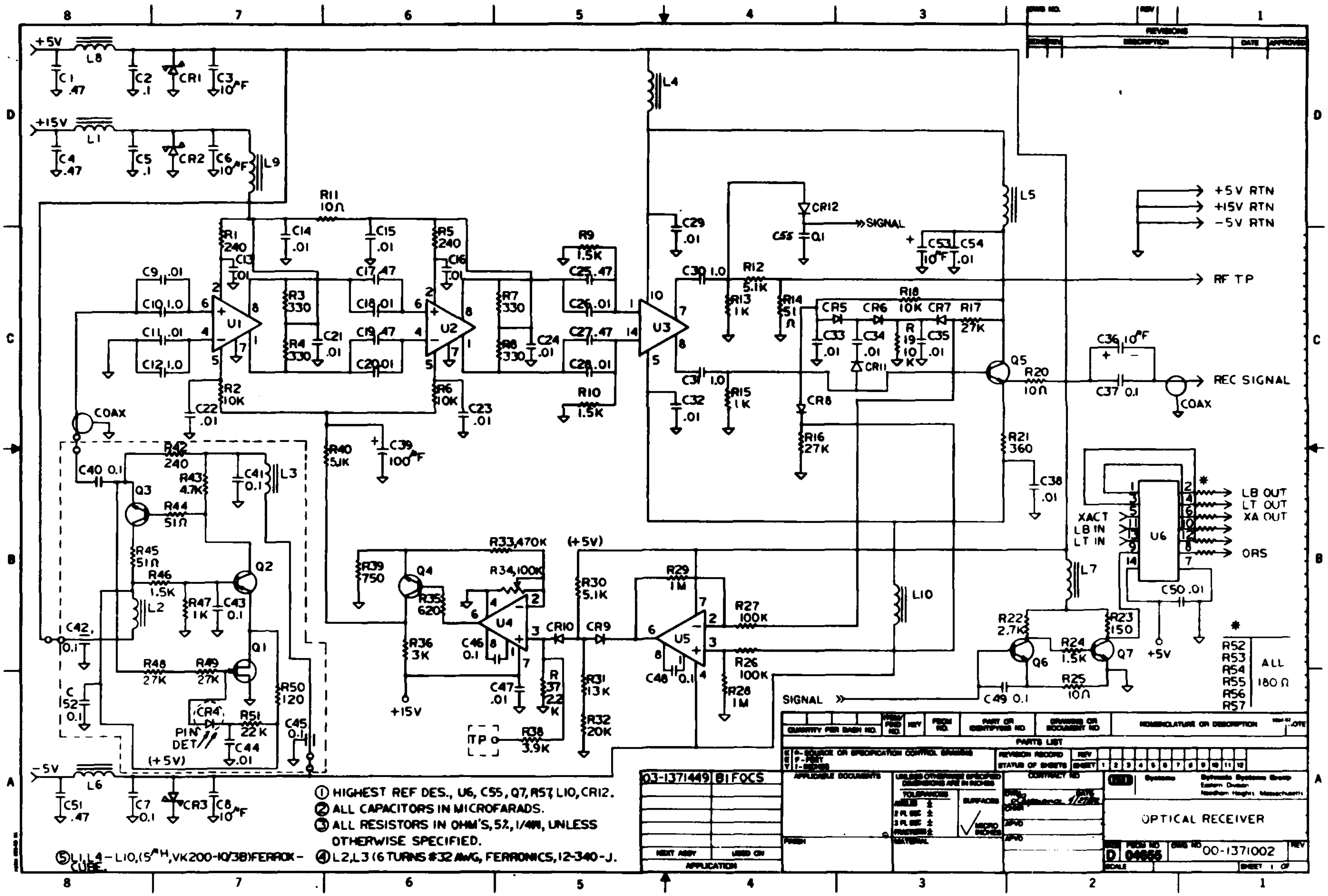


Figure 11. Receiver Schematic

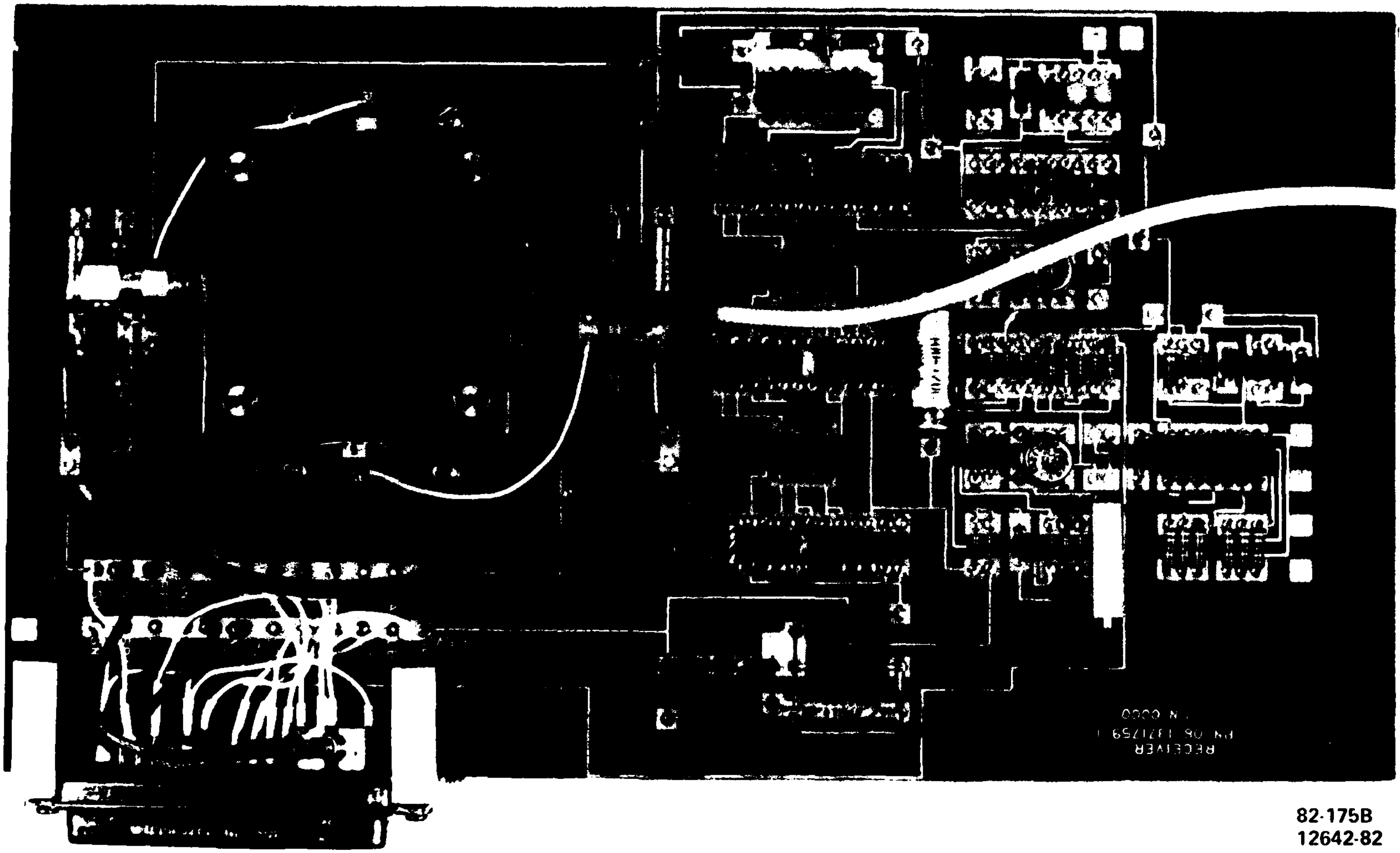

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Figure 12. Receiver Card

### 3.1.3 Encoder

#### 3.1.3.1 Description

The encoder has, as inputs, the TTL level NRZ mission bit stream (MBS) and a 20 MHz clock. The encoder output is a Manchester-encoded MBS that provides a 50% duty cycle to the optical transmission system. This duty cycle is desirable for two reasons: 1) frequent transitions ensure ease of timing recovery at the receiver end, and 2) a 50% duty cycle minimizes possible laser output power "droop" due to thermal effects. The encoder circuitry, shown in Figure 13, is on the CODEC card as shown in Figure 14. The parts list for the encoder (PN 06-1371761-1) is given in Appendix A.

#### 3.1.3.2 Performance Specifications

The encoder must operate over the voltage and frequency range of the expected inputs. The encoder is designed to operate at input data and clock voltages of 0.2 V to 0.4 V for the "0" state, and 2.4 to 2.7 volts for the"1" state. The output signal voltage levels for each state are the same as above. The frequency range for operation is 19.5 Mb/s to 20.5 Mb/s, with clock and data in phase within 15 degrees.

#### 3.1.3.3 Acceptance Limits

The encoder shall operate as specified with nominal input data and clock bit streams within the ranges stated above.

### 3.1.4 Decoder

#### 3.1.4.1 Description

The decoder extracts timing from the analog signal provided by the receiver and uses this timing (clock) signal to sample the analog signal, to regenerate the binary Manchester signal, and to convert the Manchester data stream back to NRZ. These functions are performed with emitter coupled logic (ECL) circuitry, which has greater speed than standard TTL ICs. All card interface lines are, however, TTL-implemented.

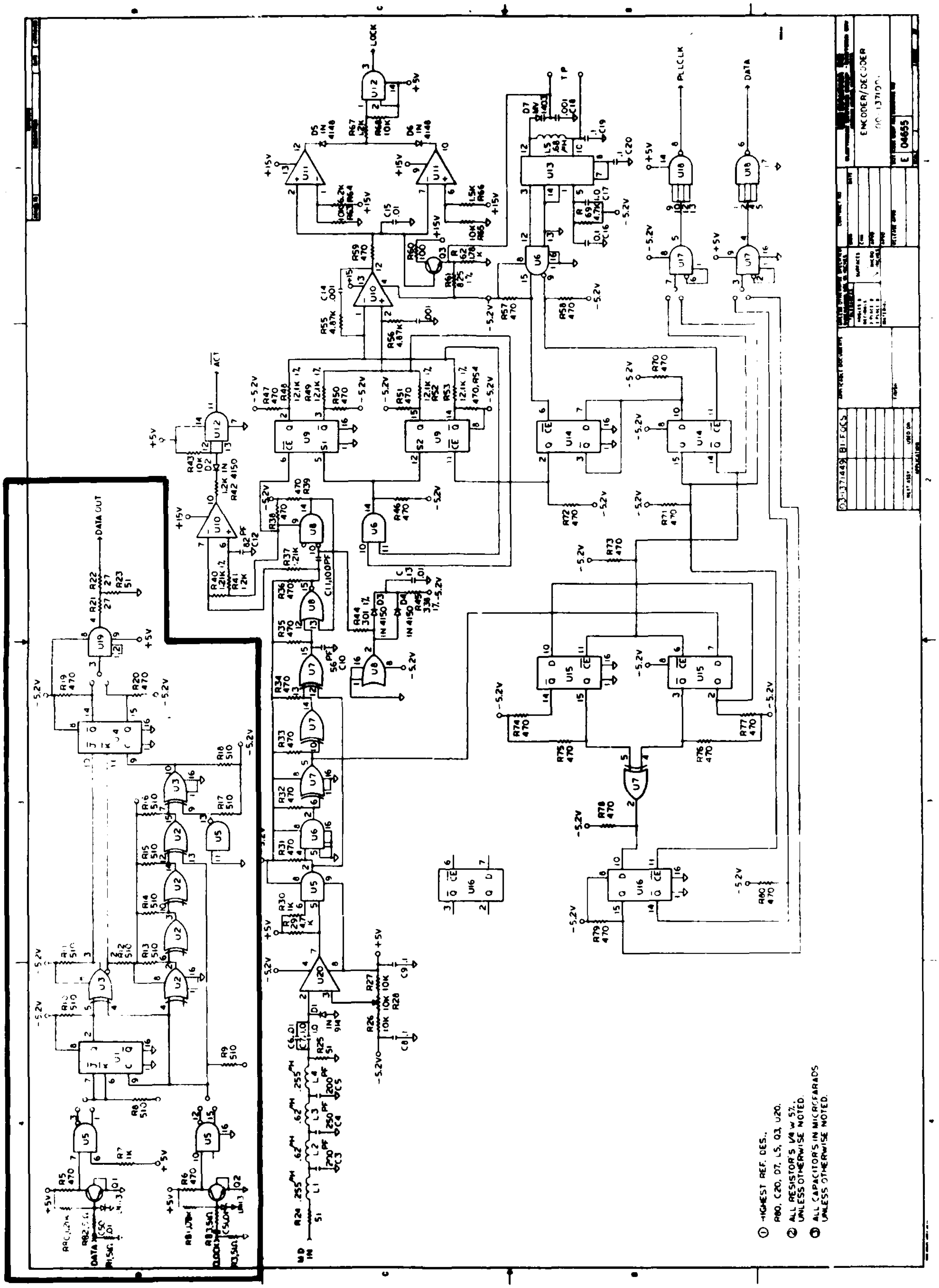


Figure 13. Encoder Schematic (Highlighted)

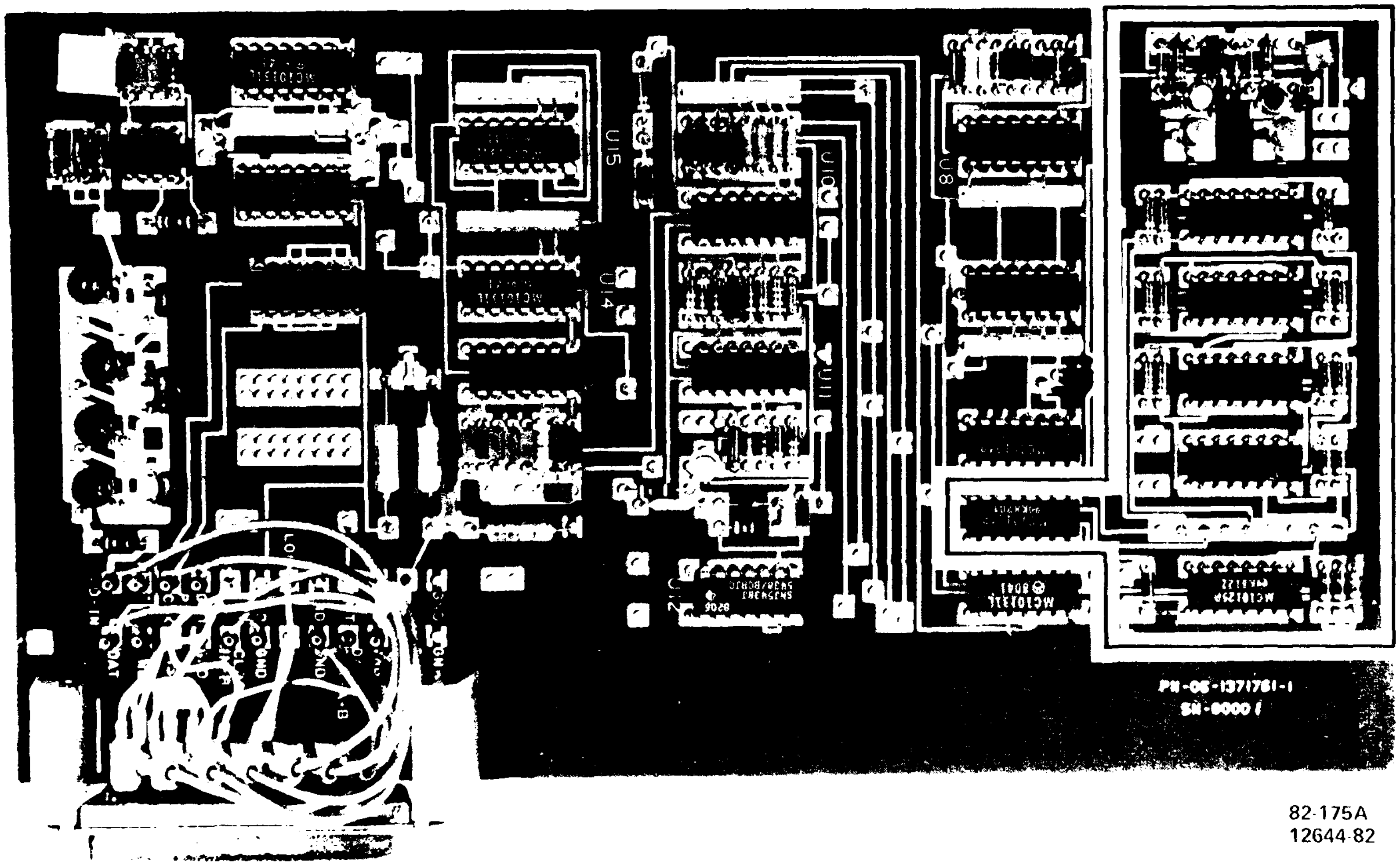


Figure 14. CODEC Card (Encoder Circuit Highlighted)

The timing extraction is performed with a phase lock loop (PLL) and, due to the frequent transitions of Manchester encoded data, the reconstituted clock is stable. Strapping is provided to change the internal data/clock phase relationship from $90^{o}$ to $270^{o}$, if required.

The çircuitry for the decoder is shown in Figure 15, and the function highlighted in the photograph of the CODEC card (Figure 16). The parts list for the decoder (PN 06-1371761-1) is given in Appendix A.

#### 3.1.4.2 Performance Specifications

The decoder must extract a clock from, and decode, an analog electrical output from the receiver for all cases when the frequency is 20 Mb/s $\pm$ 0.5 Mb/s, and the voltages are within the TTL (0.2V-0.2V, 2.4V-2.7V) specifications.

#### 3.1.4.3 Acceptance Limits

The decoder card must be capable of decoding data received from the receiver. It is recommended that the acceptance for the decoder be an in-line test with a known-functional encoder, at a temperature in the range $0^{o}C$ to $50^{o}C$.

## 3.2 SYSTEM ALARM AND CONTROL CIRCUITS

### 3.2.1 Modem Circuits

The BIFOCS modem circuits include several alarms which correspond to the front panel indicator lights. These include:

- Laser over-temperature alarm (transmitter)
- ILD over-current alarm (transmitter)
- PLL out-of-lock alarm (CODEC)
- Signal loss alarm (receiver)

### 3.2.2 Control Circuits

Control circuits necessary to adjust automatically operating parameters as required to compensate for device temperature or aging effects include:

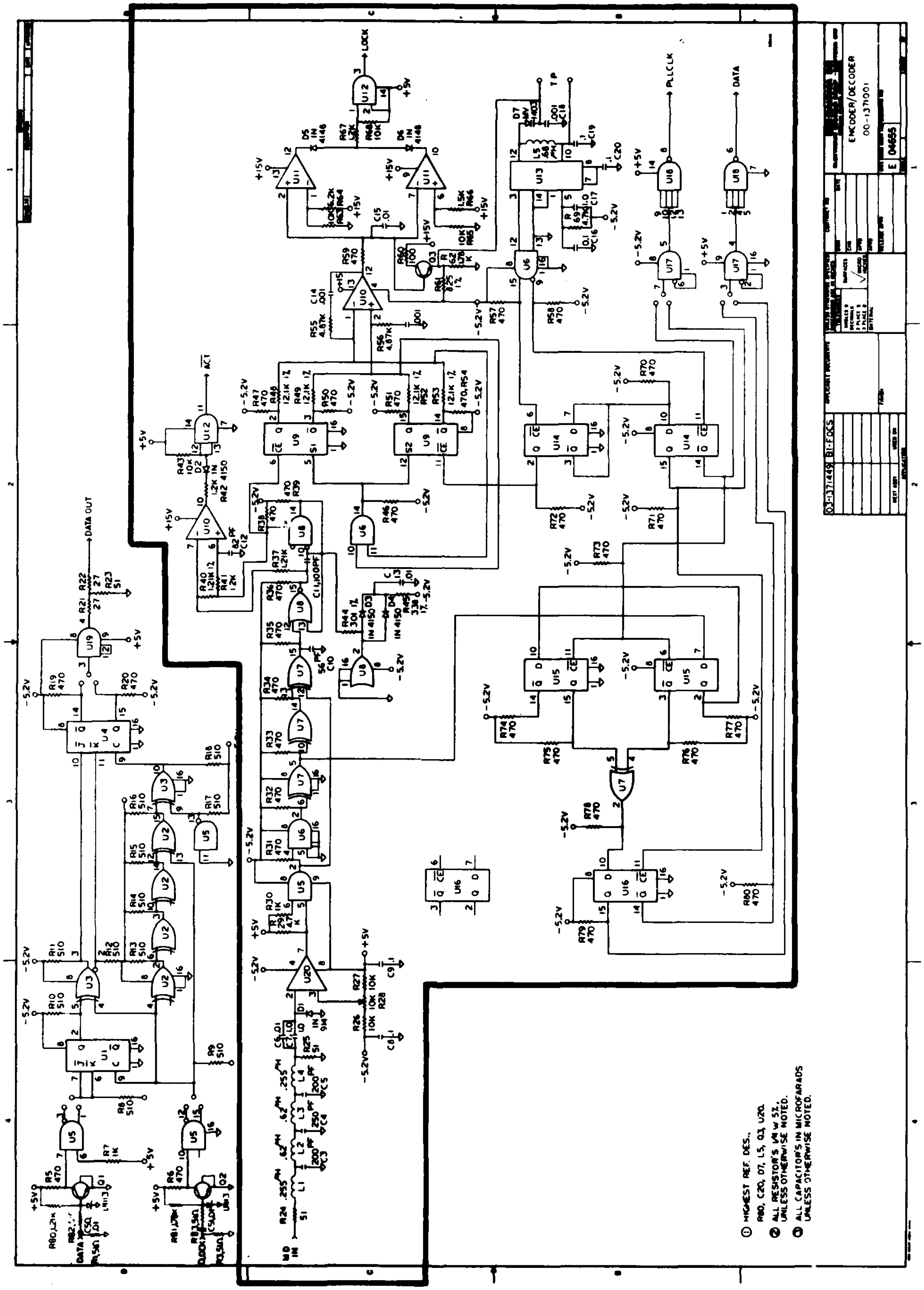


Figure 15. Decoder Schematic (Highlighted)

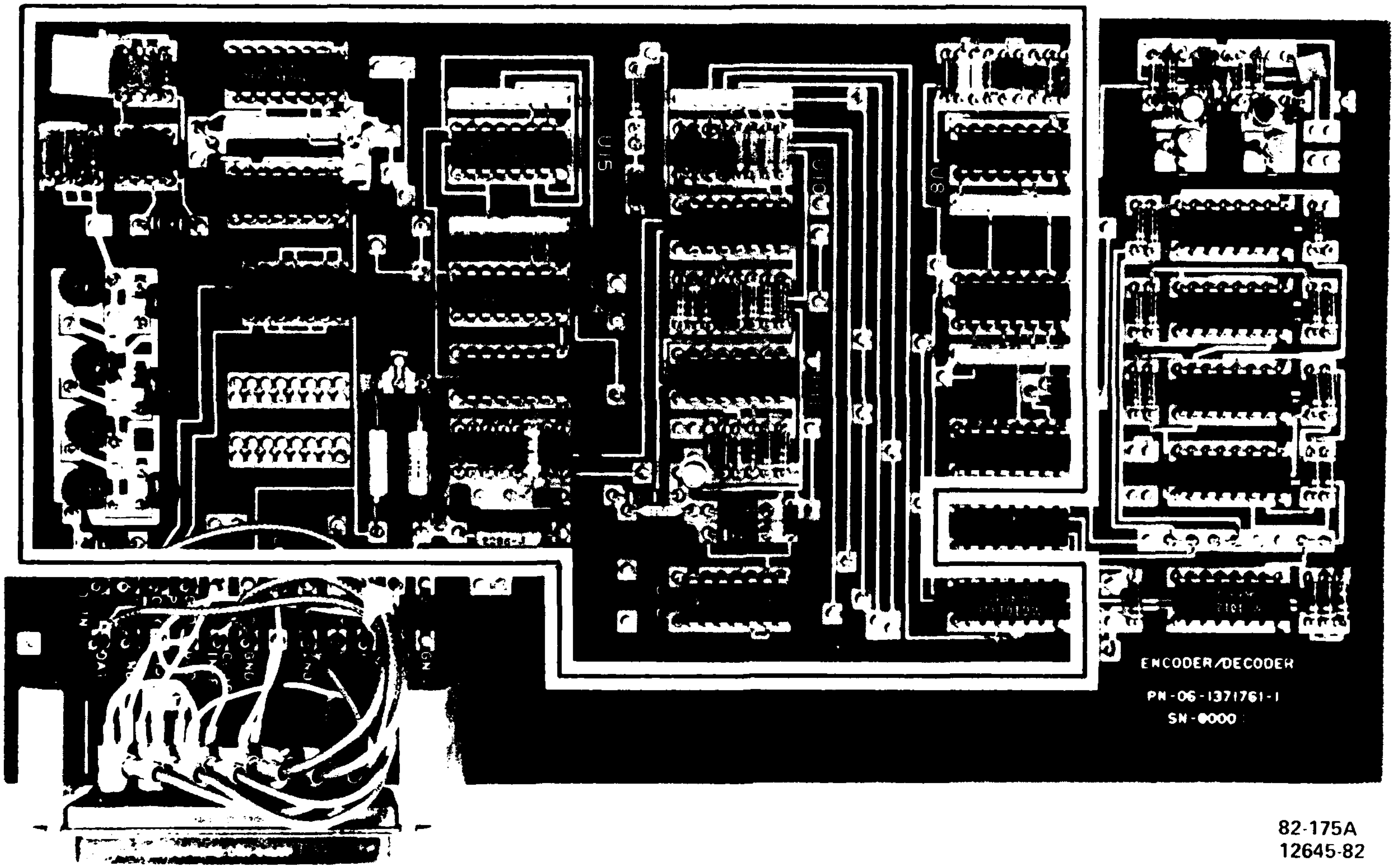


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Figure 16. CODEC Card (Decoder Circuit Highlighted)

- Thermal cooler drive circuits compatible with device characteristics (transmitter)
- Optical feedback level detection circuit (transmitter)
- Bias current level adjustment for InGaAsP threshold level (transmitter)
- Modular pulse level driver circuit (transmitter)
- Loss-of-signal laser shutoff circuit (transmitter)

## 3.3 MAJOR BIFOCS OPTICAL COMPONENTS

### 3.3.1 InGaAsP Diode Laser Module

The choice of thermoelectrically cooled InGaAsP diode laser transmitters was dictated by a realistic estimate of the link losses associated with the fiber optic cable, connectors, and duplexers. In order to provide the highest possible power margin and signal-to-noise ratio, the receivers used for the BIFOCS program contain InGaAs PIN diode detectors coupled to hybrid GaAs MESFET preamplifiers.

### 3.3.2 Optical Wavelength Duplexer

#### 3.3.2.1 Description

The duplexer is an optomechanical component that has three fibers which act as optical "Input/Output" (I/O) ports. These fibers are 50 μm core, graded index fibers and are assigned for use with specific wavelengths as shown in Figure 17. The duplexer has internal collimating lenses which make the fiber exit beams parallel (or, conversely, focus a parallel beam onto a fiber core) for more efficient beamsplitter and filter operation as shown in Section 3.3.3 (Figure 20). The 45° beamsplitter provides beam direction in accordance with the dichroic characteristics (reflect 1.31 μm, pass 1.21 μm). The supplemental 90° filters provide out-of-band attenuation of the signals since the detectors (PIN diodes) are broadband (non-selective) and there is finite out-of-band laser emission (Figures 18a and 18b).

Figure 19 is a schematic representation of the duplexer. The duplexer will be housed in a package with the approximate dimensions of 3cm X 3cm X 1.5cm.

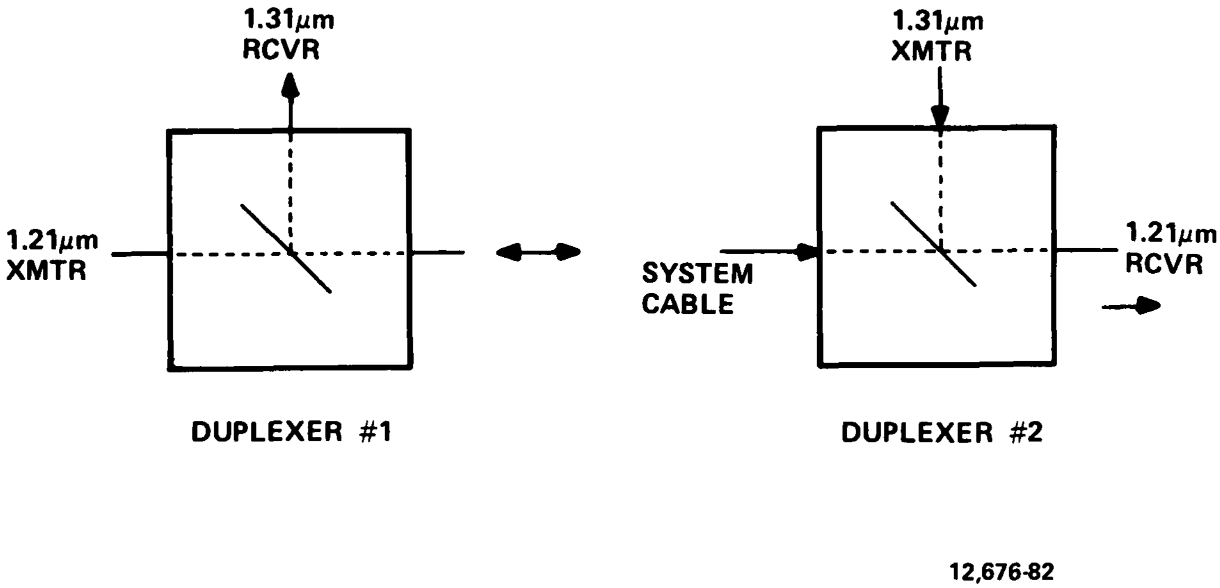


Figure 17. Duplexer Configurations

3.3.2.2 Performance Specifications

The total duplexer in-band insertion loss in either channel should not exceed -4 dB, while the total out-of-band loss in the duplexer must be -37 dB minimum (crosstalk attenuation). The duplexer must operate from $0^{o}C$ to $50^{o}C$.

3.3.2.3 Acceptance Limits

The duplexer must exhibit the following performance when used with the modem lasers and tested per the Test Plan.

a. In-Band Insertion Loss . . . -4 dB maximum

b. Out-of Band Crosstalk Rejection . . . -37 dB minimum

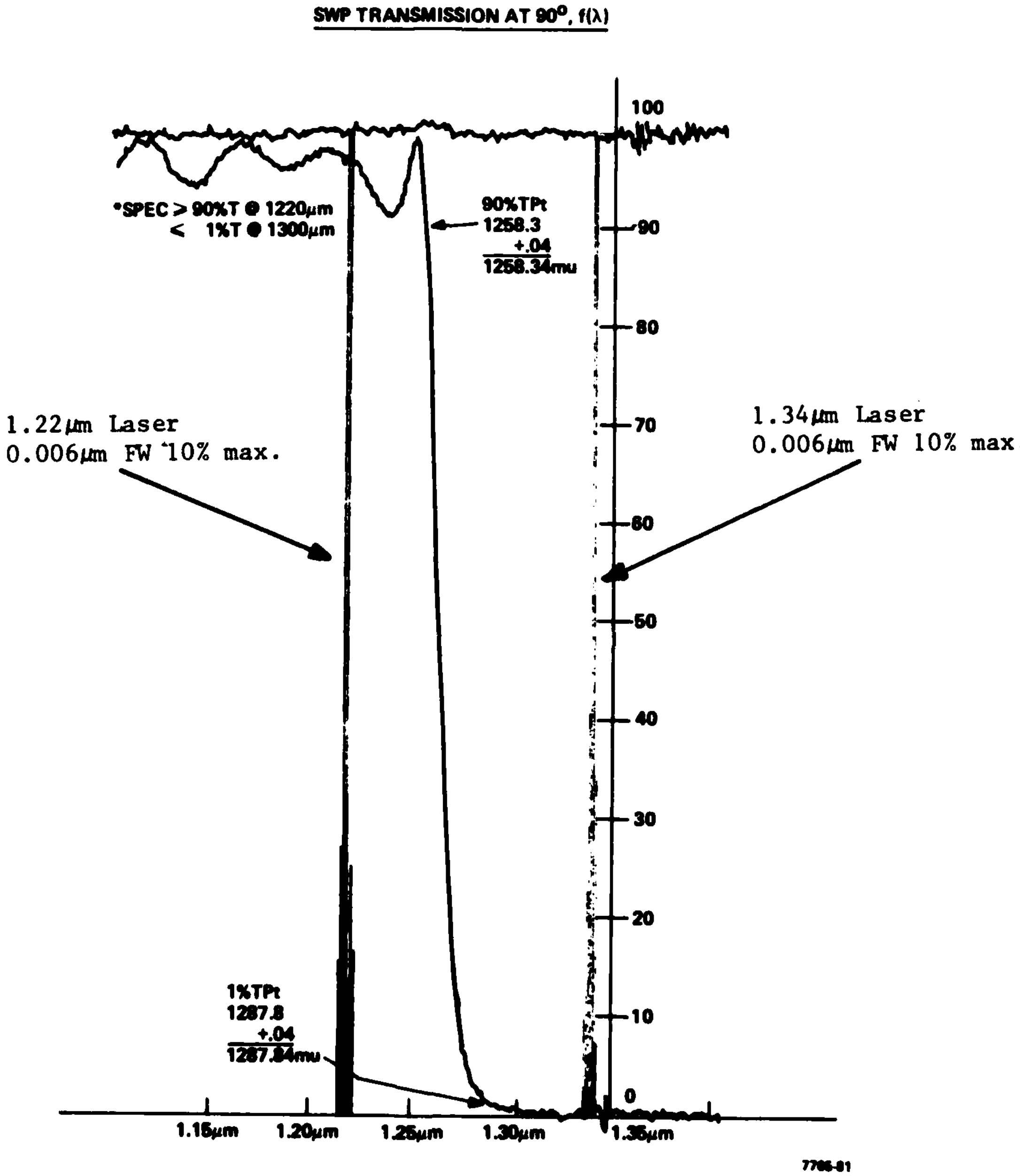


Figure 18a. SWP Transmission at 90°, f (λ)

LWP TRANSMISSION, AT 90°, f (λ)

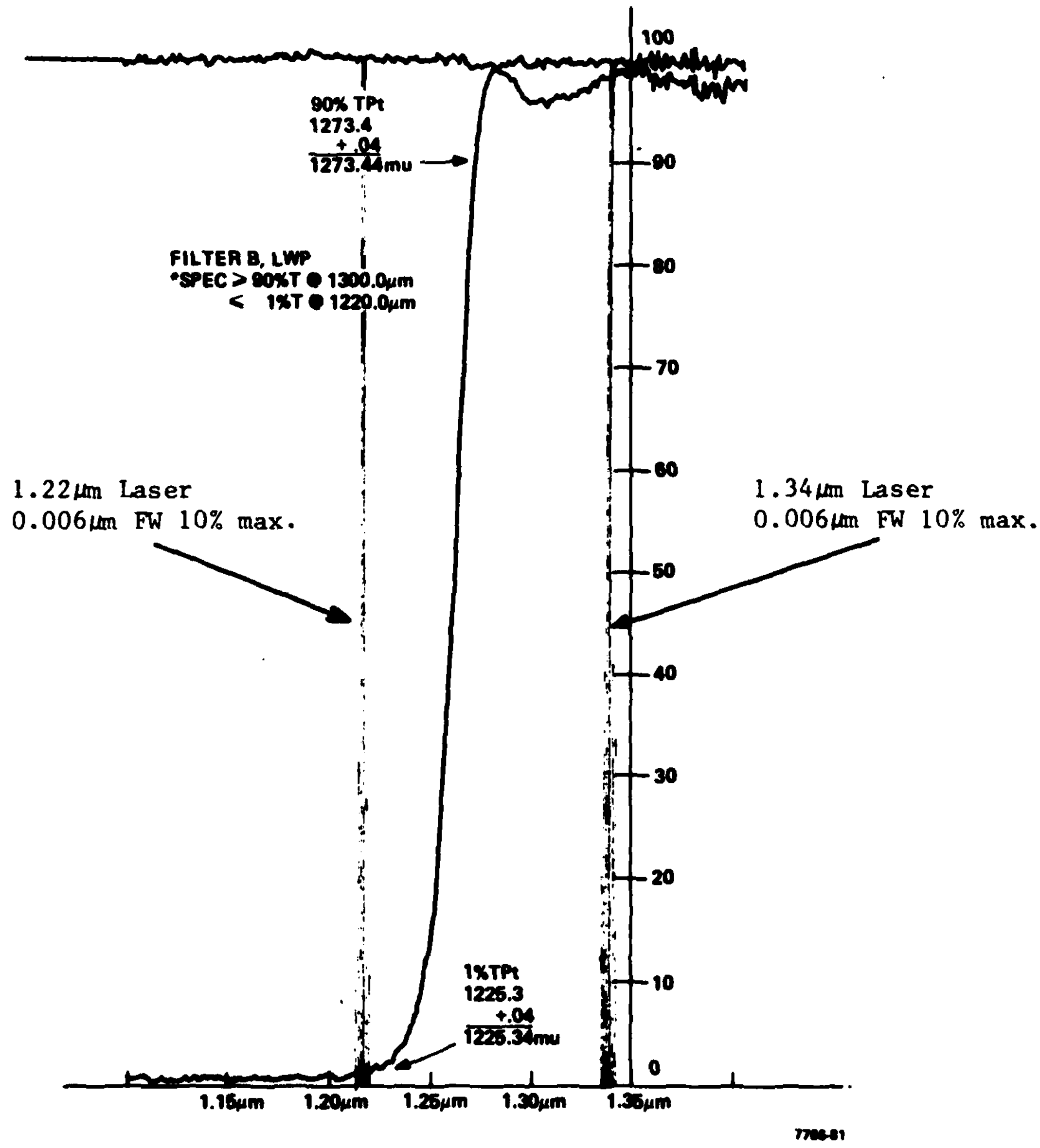


Figure 18b. LWP Transmission at 90°, f (λ)

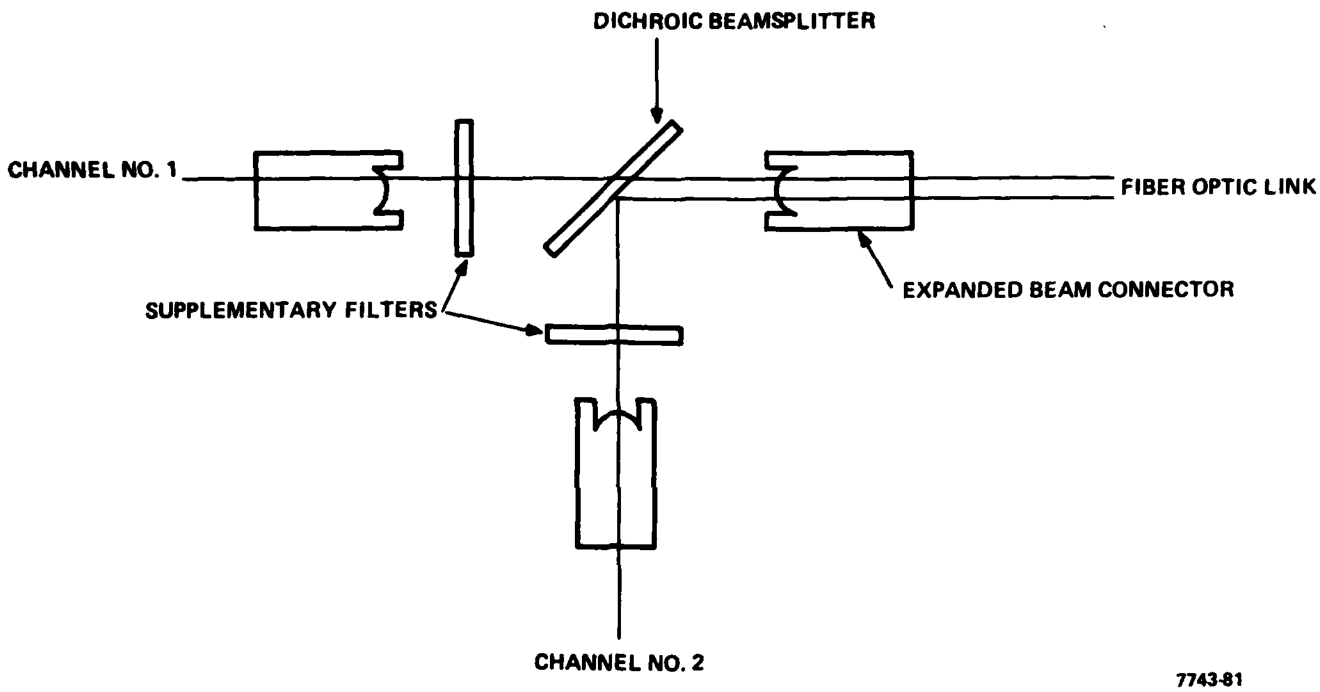


Figure 19. GTE Optical Wavelength Duplexer

3.3.3 GTE Expanded Beam Microlens

The GTE expanded beam microlens (see Figures 20 & 21) is a collimating lens housed inside the duplexer. The function of the lenses is to make the fiber exit beams parallel (or, conversely, focus a parallel beam onto a fiber core), resulting in a more efficient beamsplitter and filter operation.

3.3.4 Dichroic Beamsplitter and Filters

The 45° dichroic beamsplitter and supplementary normal-incidence dichroic filters used in the optical wavelength duplexer represent state-of-the-art designs developed through a joint effort of GTE Laboratories and Optical Coating Laboratories, Inc. At the wavelengths of 1.21 µm and 1.31 µm, the beamsplitter transmittance and reflectance are independent of the polarization of the incident light beam, resulting in a very low insertion loss for the unpolarized light emitted from the optical fibers. The worst-case insertion loss in each wavelength-multiplexed optical channel is less than the 4 dB maximum allotted by the link power budget.

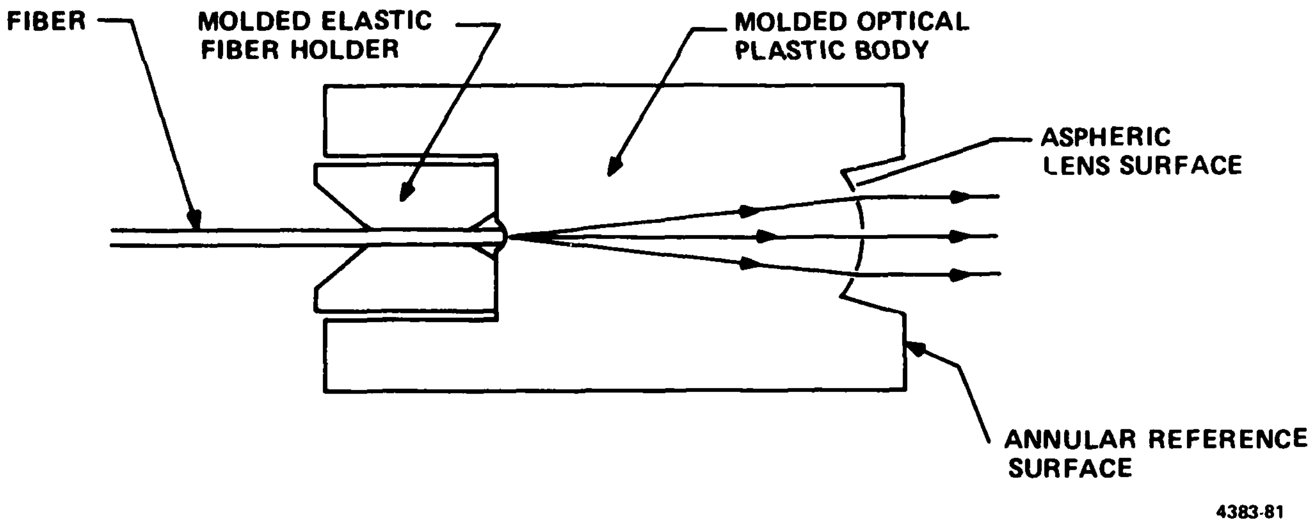


Figure 20. Schematic of GTE Microlens

A dichroic beamsplitter approach was selected over possible prism or grating designs for the duplexer device on the basis of the dichroic duplexer's high performance, mechanical simplicity, and potential for satisfying tactical environmental requirements. The operating wavelengths of 1.21 μm and 1.31 μm correspond to the largest interchannel wavelength separation that is consistent with a low-absorption band in the spectral characteristic of the molded plastic collimating connectors.

The optical specifications for the dichroic beamsplitter optical wavelength duplexer were established by the analyses conducted on the link power budget and crosstalk of the system. Tables 3 and 4 summarize the analyses.

The measured optical characteristics of the dichroic beamsplitter and supplementary filter and the resulting duplexer crosstalk characteristics are summarized in Tables 5 and 6 respectively.

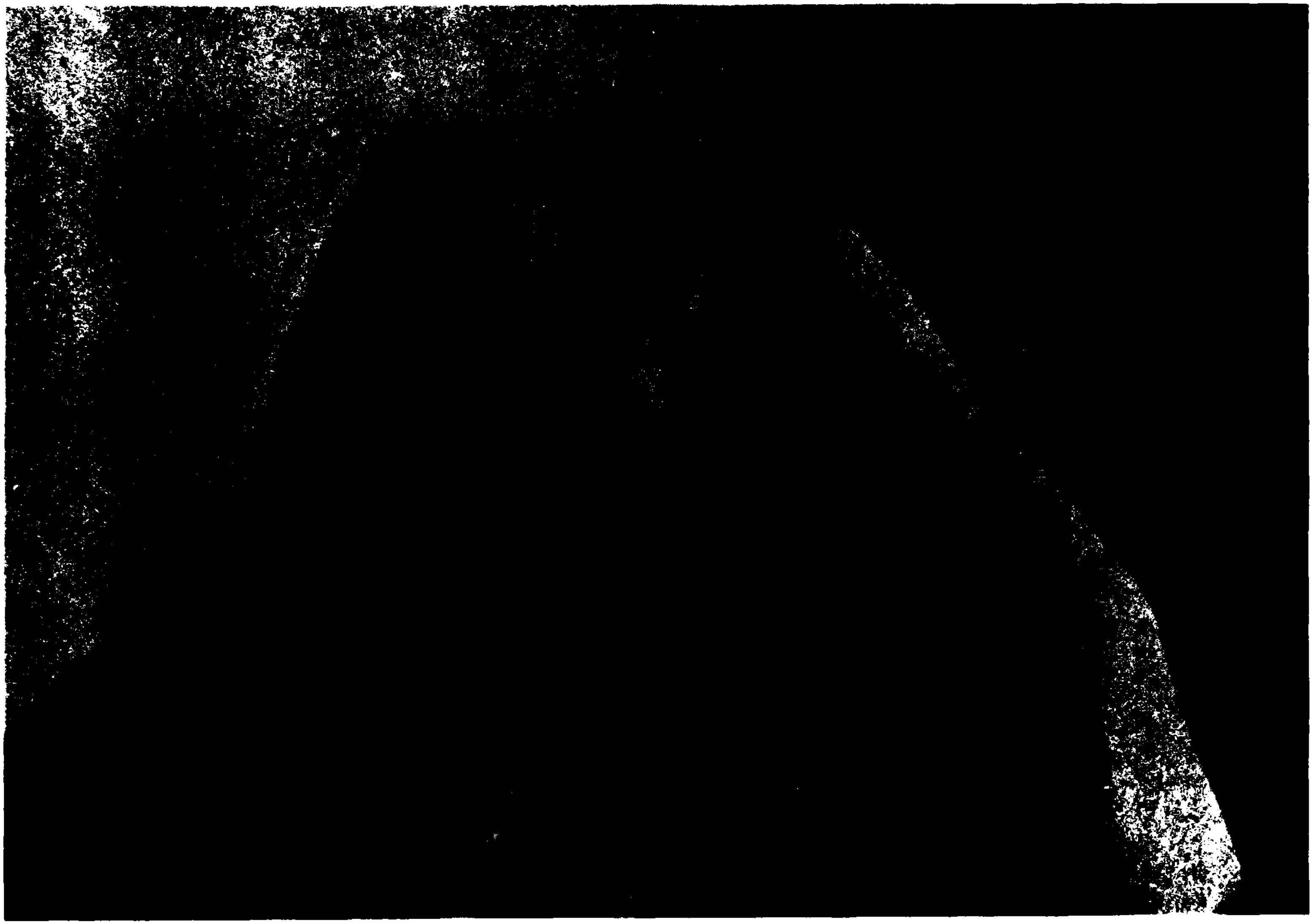

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Figure 21. GTE Microlens (Used in Connectors and Duplexer)

TABLE 3. LINK POWER BUDGET ANALYSIS

| | | |
|---|---|---|
| Laser power output | + 0 dBm | |
| Receiver sensitivity | -45 dBm | |
| Power available for losses | 45 dB | |

| Worst-case losses (dB) | 10 km | 15 km |
|---|---|---|
| Cable losses (1.5 dB/km) | 15 | 22.5 |
| Connector loss (1.5 dB/conn) | 9 | 13.5 |
| Duplexer losses | 6 | 6 |
| Total losses | 30 | 42 |
| Power margin | 15 dB | 3 dB |

TABLE 4. CROSSTALK ANALYSIS

| | 10 km | 15 km |
|---|---|---|
| Expected receiver power | -30 dBm | -42 dBm |
| Desired margin | 6 dB | 3 dB |
| Worst-case receiver power | -36 dBm | -45 dBm |
| Required crosstalk attenuation* | -12 dB | -12 dB |
| Maximum permissible crosstalk power | -48 dBm | -57 dBm |
| Source power output | + 0 dBm | + 0 dBm |
| Required crosstalk isolation | 48 dB | 57 dB |

* 12 dB for $10^{-9}$ BER

TABLE 5. BEAMSPLITTER AND FILTER CHARACTERISTICS

| Component | Wavelength | |
|---|---|---|
| | 1.21 μm ( λ1) | 1.31um (λ2) |
| 45° Beamsplitter | T = - 0.36<br>R = - 14.0 | T = - 18.0<br>R = - 0.13 |
| Long-Wave-Pass Filter | T = - 23.0 | T = - 0.18 |
| Short-Wave-Pass Filter | T = - 0.18 | T = - 23.0 |

T = Transmission Loss (dB) R = Reflection Loss (dB)

TABLE 6. DUPLEXER CROSSTALK CHARACTERISTICS

| Item (See Section 3.3.5.3) | Channel #1 | Channel #2 |
|---|---|---|
| | λ2 -> λ1 | λ1 -> λ2 |
| Internal Crosstalk | < -80 dB | < -80 dB |
| External Crosstalk | -41 dB | -37 dB |

It can be seen that the supplementary dichroic filters on the receiver ports of the duplexers provide adequate external backscatter rejection for a 15 km link length. The difference between the crosstalk and loss characteristics of the 1.21 μm and 1.31 μm channels results from the use of identical dichroic beamsplitters at each end of the link in order to reduce system cost and parts proliferation.

### 3.3.5 Precision Duplexer Package

The requirement of the duplexer package is to maintain the alignment of the lenses, beamsplitter and filter so as to minimize optical insertion loss and maximize optical channel separation. Consequently, maintaining the alignment tolerances of the system is critical.

To maintain these tolerances, GTE conducted a computer ray-trace analysis of insertion loss due to lens tilt and offset to define

machining tolerances for the duplexer package, and a ray-trace analysis to determine thickness and parallelism tolerances for beamsplitter and filter substrates. In addition, the worst case tilt between reflected beams and the worst case offset between transmitted beams in the duplexer had to be such as to result in a negligible increase in insertion loss.

#### 3.3.5.1 Critical Design Parameters

The critical design parameters of the system are:

a. Angular - The most critical and difficult to attain and control (part of design - adjustable)

b. Axial (precision machined, adjustable)

c. End separation (less critical with use of collimating lenses)

d. Adjustability (part of design)

e. Manufacturability (part of design)

#### 3.3.5.2 Predicted Loss Characteristics of Duplexer Based on Measured Beamsplitter and Filter Characteristics

| COMPONENT | LOSSES | |
|---|---|---|
| | 1.21 μm ( λ1) | 1.31 μm ( λ 2) |
| Beamsplitter | <.4 dB | <.2 dB |
| Supplementary Filters | <.2 dB | <.2 dB |
| Expanded Beam Connectors (4 per channel; <.7 dB each) | <2.8 dB | <2.8 dB |
| Total WDM Loss (2 Beamsplitters, 2 Filters and 4 connectors per channel) | <4.0 dB | <3.6 dB |

Note: The measured characteristics of the beamsplitter and filters indicate that the WDM loss will be less than 4 dB.

### 3.3.5.3 Crosstalk In Duplexed System

The most critical system parameter of the duplexer is the crosstalk, specified as the dB ratio of the unwanted optical signal to the optical signal measured at the receiver input. Sources of crosstalk are shown in Figure 22, and are classified as internal (duplexer-generated) or external (caused outside duplexer). The system specifications require suppression of optical crosstalk to less than -12 dB in each channel. From Table 4 it is seen that the optical duplexer must therefore have less than -42 dB and -54 dB of internal crosstalk for the 10 and 15 km links, respectively, in order to maintain the required system bit error rate. Assuming that the external backscatter from the optical fiber link is at most -20 dB, the duplexer must also provide at least 34 dB of external backscatter rejection. This -34 dB external crosstalk figure neglects the spontaneous wideband emission from the InGaAsP diode lasers.

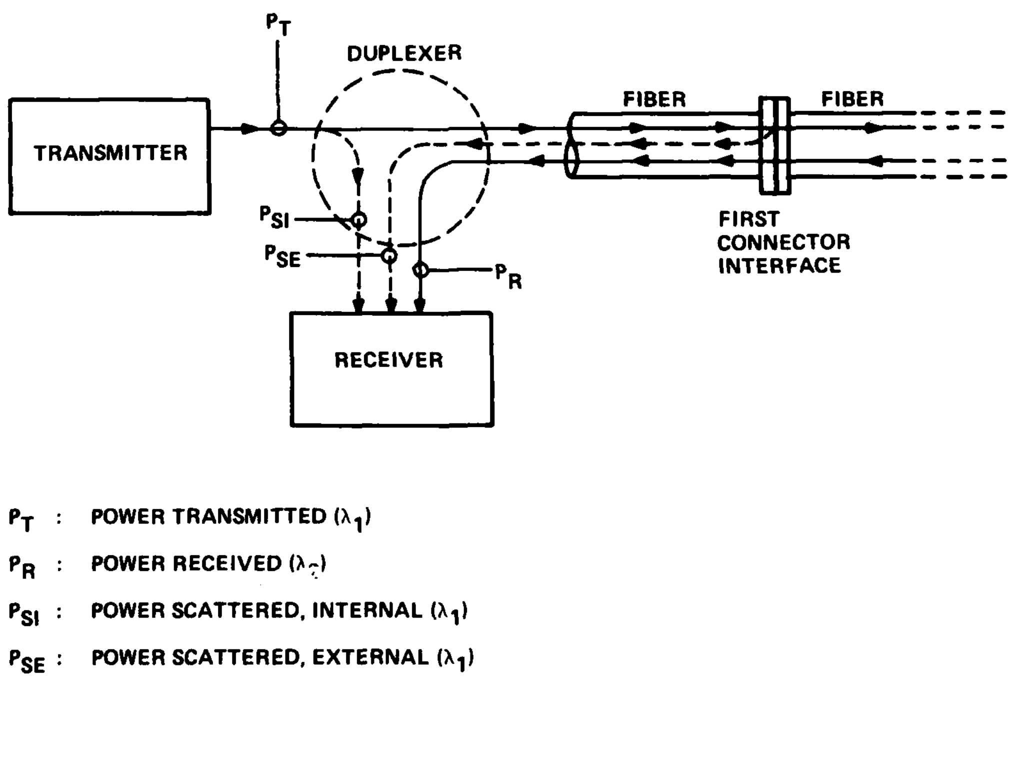


Figure 22. Sources of Crosstalk in Duplexed System

Measurements of wideband spontaneous emissions of the InGaAsP diode lasers were made at GTE Laboratories. These measurements indicate that the total spontaneous emission is less than -3 dBm for a diode laser emitting 6 dBm of nearly monochromatic stimulated emission. The process of coupling the diode laser to a low-NA optical fiber selectively attenuates the spontaneous emission. When the level of stimulated emission radiating from the fiber pigtail of a coupled laser is 0 dBm, the total spontaneous emission is only -18 dBm. Since less than half of the spontaneous emission spectrum falls within the passband of the other optical channel, a fiber backscatter of -20 dB could result in an interfering signal level of as much as -41 dBm at the detector. In order to overcome this problem, the GTE optical wavelength duplexer includes a normal-incidence dichroic filter at the transmitter port which reduces the crosstalk from spontaneous emission by at least 20 dB. With the interfering signal level from spontaneous emission reduced to less than -61 dBm, this source of crosstalk is no longer a limitation to system performance at any link length.

#### 3.3.5.3.1 Predicted Crosstalk Characteristics of Duplexer (Based on Measured Beamsplitter and Filter Characteristics

- Internal crosstalk is negligible (≈-80dB) due to good surface quality of beamsplitter
- External crosstalk is -41 dB in 1.21 μm channel and -37 dB in 1.31 μm channel
  - Beamsplitter plate alone allows -18 dB crosstalk in 1.21 μm channel and -14 dB crosstalk in 1.31 μm channel
  - Supplementary filters reduce crosstalk by an additional 23 dB in each channel

### 3.3.6 Low Loss Cable and Bulkhead Connectors

The cable and bulkhead connectors utilize the same GTE molded plastic collimating lens as the duplexer. The lenses are mounted in prototype plastic backshells which permit the connector to have relatively loose tolerances with very low connector loss. This is due to the incorporation of all the critical alignment parameters within

the molded lens itself. The lens was shown previously in Figures 20 and 21.

### 3.3.7 Internal Splice Assemblies

The pigtailed transmitter and receiver cards are optically connected to the duplexers with GTE elastomeric splices mounted in splice housings. Figure 23 shows such a splice mounted in its housing. The splice, which actually aligns the fiber ends relative to each other, is the small cylinder in the center of the splice housing.

#### 3.3.7.1 GTE Elastomeric Splice

The elastomeric splice aligns and holds the fiber ends by axially aligning the fibers by means of restoring forces applied to the outer diameters of the fiber. These forces result from the slight distortion of the elastomer when the fiber is inserted. As shown in Figure 24, this device, unlike V-groove alignment devices, permits precise alignment even when the fiber diameters are unequal.

#### 3.3.7.2 Splice Housing

The splice housing, together with the splices, provides the functions of initial fiber alignment prior to insertion into the splice, guiding of the fiber into the splices, fiber jacket strain relief, and protection of the completed splice.

## 4.1 FINAL REPORT CONCLUSIONS AND RECOMMENDATIONS

The BIFOCS system operated as required over the full 15 km cable assembly plant at room temperature, and thereby demonstrated the feasibility of wavelength division multiplexing in a tactical, connectorized system. Just prior to temperature testing, the 1.3 μm laser failed and was replaced with a less optimum unit. When this unit did not perform adequately in the system, it was replaced with a unit of more appropriate wavelength and extinction ratio, but which was strongly modal. This, unfortunately, led to a significant increase in the noise in that channel and the 1.3 μm channel did not again operate as well as with the original laser.


Figure 23. GTE Elastomeric Splice and Housing

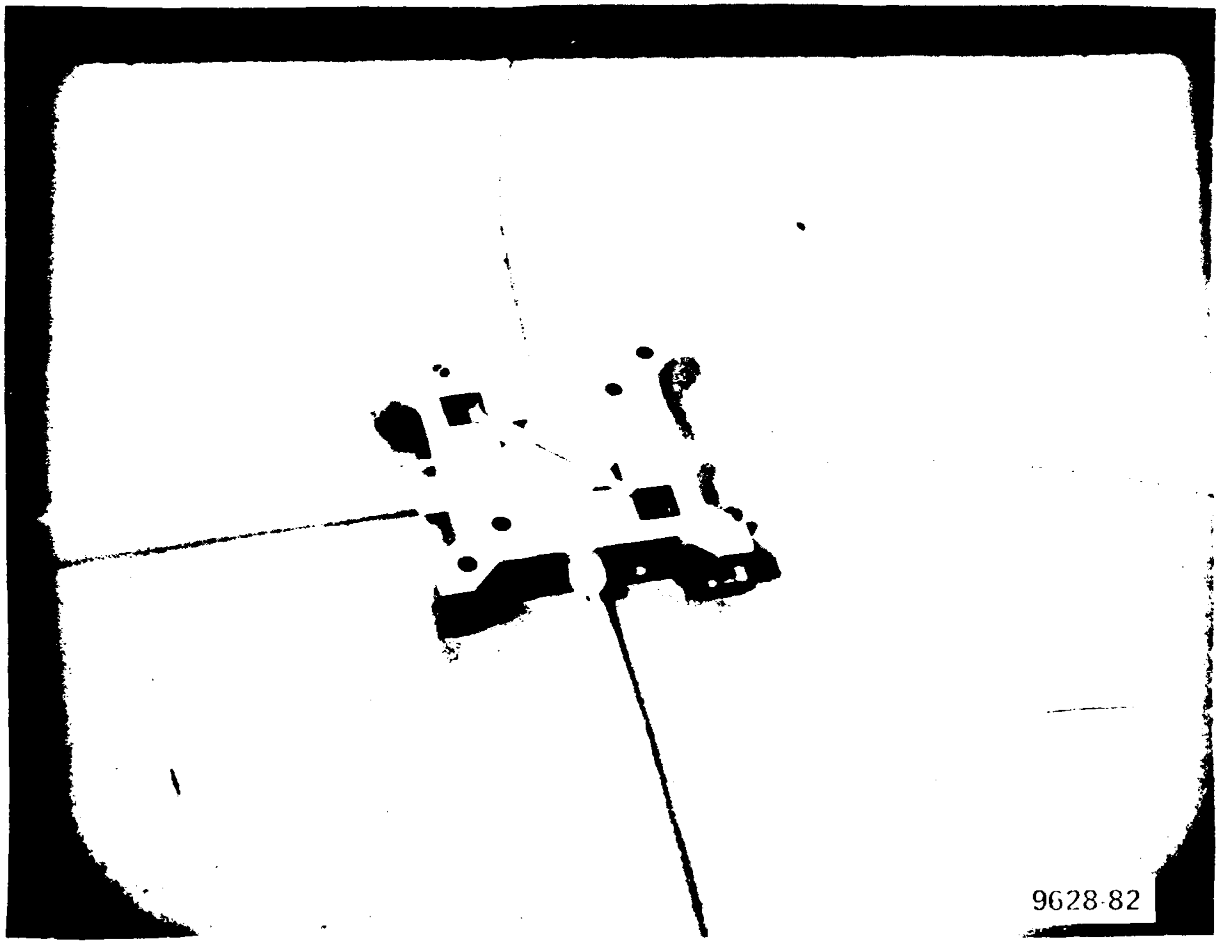

Figure 24. Elastomeric Splice Operation

Certain receiver and cable assembly anomalies also arose during temperature testing and were considered due to the fact that these items were adaptations of previously designed items, and not specifically designed for temperature variations.

Thus while the BIFOCS development model demonstrated the feasibility of using wavelength division multiplexing (OWM) as a means of achieving tactical bidirectional communication over a single fiber cable, it also highlighted several technical areas in which normal component variations typical of current production tolerances are excessive for assured reliable, reproducible system operation.

Emitter characteristics requiring very rigid control or specification are output spectrum and modal structure. These parameters must be tightly defined in order to minimize performance variations of other system components. Other components, such as cable assemblies, connectors, and duplexers, are very sensitive to small variations in wavelength (approximately 0.02 $\mu$m) and/or modal distribution. While long-term (>2 bit times) variations alter the basic operational efficiency of passive components, short-term effects manifest themselves as noise, reducing the signal-to-noise ratio. Control of emitter parameters, including precise wavelength and modal distribution, is therefore necessary at this time to ensure consistent operational performance. Unless this rigid parametric control is assured, system performance may be compromised. This condition could be improved by utilizing several techniques, including emitter tuning by means of temperature, or the use of component materials with different absorption bands.

# APPENDIX A

# PARTS LISTS

| PARTS LIST | CKTCDASSY-EN/DC | PL06-1371761-1 | PL REV -- |
|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371761-1 | | | |

| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
|---|---|---|---|---|---|---|---|
| 1 | 1 | | 04655 | 06-1371761-101 | | PC CKT CARD ASY | |
| 2 | 1 | | 04655 | 73-588394-1 | | CONNECTOR | |
| 3 | 2 | | 04655 | 13-588453-1<br>A406 AMPEREX | | TRANSISTOR | Q1, Q2 |
| 4 | 2 | | 04655 | 15-588438-1<br>MC10135 | | DUAL J-K FLIP F | U1, U4 |
| 5 | 2 | | 04655 | 15-588058-1 | | IC, TYPE 10113 | U2, U7 |
| 6 | 1 | | 04655 | 15-587992-1 | | IC, TYPE 10107 | U3 |
| 7 | 2 | | 04655 | 15-587995-1 | | IC, TYPE 10125 | U17,U19 |
| 8 | 1 | | 04655 | 15-587994-1 | | IC, TYPE 10124 | U5 |
| 9 | 1 | | 04655 | 15-588057-1 | | IC, TYPE 10104 | U6 |
| 10 | 1 | | 04655 | 15-587990-1 | | IC, TYPE 10102 | U8 |
| 11 | 4 | | 04655 | 15-587996-1 | | IC, TYPE 10131 | U9,14,15,16 |
| 12 | 2 | | 04655 | 15-586416-1 | | IC, TYPE 747 | U10, U11 |
| 13 | 1 | | 04655 | 15-588022-1 | | IC, TYPE 7438 | U12 |
| 14 | 1 | | 04655 | 15-587972-1 | | IC, TYPE 1648 | U13 |
| 15 | 6 | | | | 750-81-R470 | RESISTOR PACK | PULL DOWN RESISTOR |
| 16 | 1 | | 81349 | RCR07G101J3S | MIL-R-39008/1 | RES.,FXD,CMPSN | R60 |
| 17 | 1 | | 81349 | RN55D3010F | MIL-R-10509/7 | RES.,FXD, FILM | R44 |
| 18 | 1 | | 81349 | RN55D3380F | MIL-R-10509/7 | RES.,FXD, FILM | R45 |

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| PARTS LIST | | | | CKTCDASSY-EN/DC | PL06-1371761-1 | | PL REV -- |
|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371761-1 | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
| 19 | 6 | | 81349 | RCR07G471JS | MIL-R-39008/1 | RES.,FXD,CMPSN | PULL DOWN RESISTOR |
| 20 | 11 | | 81849 | RCRO7G511JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R8,9,10, R11 to R18 |
| 21 | REF | | | OPEN | | FOR FUTURE USE | |
| 22 | 7 | | 81349 | RCR07G510JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R1,3,23,24, 25, 82, 83 |
| 23 | 1 | | 81349 | RN55D8250F | MIL-R-10509/7 | RES.,FXD,FILM | R61 |
| 24 | 2 | | 81349 | RCR07G102JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R7, R30 |
| 25 | 2 | | 81349 | RCR07G270JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R21, R22 |
| 26 | 6 | | 81349 | RN55D1211F | MIL-R-10509/7 | RES.,FXD,FILM | R37, 40, 42, 44, 67, 80 |
| 27 | 1 | | 81349 | RCR07G152J3 | MIL-R-39008/1 | RES.,FXD,CMPSN | R66 |
| 28 | 2 | | 81349 | RN55D1781F | MIL-R-10509/7 | RES.,FXD,FILM | R62, R81 |
| 29 | 2 | | 81349 | RCR07G472JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R69, R29 |
| 30 | 2 | | 81349 | RN55D4871F | MIL-R-10509/7 | RES.,FXD,FILM | R55, R56 |
| 31 | REF | | | OPEN | | FOR FUTURE USE | |
| 32 | 7 | | 81349 | RCR07G103JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R26, 27, 43, 63, 64, 65, 68 |
| 33 | 4 | | 81349 | RN55D1212F | MIL-R-10509/7 | RES., FXD, FILM | R48, 49, 52, 53 |
| 34 | 1 | | 81349 | CK05BX560K | MIL-C-11015/18 | CAP.,FIXED,CER | C10 |
| 35 | 2 | | 81349 | CK05BX820K | MIL-C-11015/18 | CAP.,FIXED,CER | C12 |
| 36 | 1 | | 81349 | CK05BX101K | MIL-C-11015/18 | CAP.,FIXED,CER | C11 |
| 37 | 2 | | 81349 | CK05BX102K | MIL-C-11015/18 | CAP.,FIXED,CER | C14, 18 |
| 38 | 5 | | 81349 | CK05BX103K | MIL-C-11015/18 | CAP.,FIXED,CER | C6, 13, 15, 50, 51 |

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| PARTS LIST | | | CKTCDASSY-EN/DC | | PL06-1371761-1 | | PL REV -- |
|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371761-1 | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
| 39 | 23 | | 81349 | CK05BX104K | MIL-C-11015/18 | CAP.,FIXED,CER | C1, 2, 8, 9, 16, 19, 20, PLUS ac FILTER CAP FOR ICs |
| 40 | 2 | | 81349 | M39003/01-2286 10 μF | MIL-C-39003/1 FILTER CAP. | CAP.,FXD,ELCTLT | |
| 41 | 1 | | 81349 | M39003/01-2254 4.7 μF | MIL-C-39003/1 FILTER CAP. | CAP.,FXD,ELCTLT | |
| 42 | 2 | | 81349 | JAN1N4148 | MIL-S-19500/116 | SEMICON DEV,DIO | D5, D6 |
| 43 | 3 | | 81349 | JAN1N4150 | MIL-S-19500/231 | SEMICON DEV,DIO | D2, 3, 4, |
| 44 | REF | | | OPEN | | FOR FUTURE USE | |
| 45 | 1 | | 04655 | 13-588455-1 | MU1403 | DIODE | D7 |
| 46 | 1 | | 81349 | JAN2N2222 | MIL-S-19500/255 | TRANSISTOR | Q3 |
| 47 | REF | | | OPEN | | FOR FUTURE USE | |
| 48 | 1 | | 04655 | 50-588451-1 | | COIL | L4 |
| 49 | 2 | | 04655 | 50-588450-1 | | COIL | L2, 3 |
| 50 | 1 | | 04655 | 15-586782-1 | | IC. TYPE 360 | U20 |
| 51 | 1 | | 04655 | 15-586781-1 | | IC. TYPE 74S140 | U18 |
| 52 | REF | | | OPEN | | FOR FUTURE USE | |
| 53 | 1 | | | 9250-681 | | INDUCTOR,0.68μH | L5 |
| 54 | 1 | | | | BOURNS 3262P-10K | 10K VARIABLE RESISTOR | R28 |
| 55 | 1 | | | 250pF | DM-251J | CAP., FXD, CER. | C4 |
| 56 | 2 | | | 240pF | DM-241J | CAP., FXD, CER. | C3, C5 |
| 57 | 2 | | | LM113 | | DIODE, ZENER | D10, D11 |

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| PARTS LIST | | | CKTCDASSY-RCVR | | PL06-1371759-1 | | PL REV -- |
|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371759-1 | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
| 1 | 1 | | 04655 | 06-1371759-101 | | PC CKT CARD ASY | |
| 2 | 1 | | 04655 | 73-588394-1 | | CONNECTOR | |
| 3 | 2 | | 04655 | 15-588435-1 | MC1349P | INTEGRATED CKT | U1, U2 |
| 4 | 1 | | 04655 | 15-588436-1 | LM733CN | INTEGRATED CKT | U3 |
| 5 | 2 | | 04655 | 15-588437-1 | CA3130A | INTEGRATED CKT | U4, U5 |
| 6 | 1 | | | 15-586448-1 | SN5406J | INTEGRATED CKT | U6 |
| 7 | 2 | | 81349 | RCR07G100JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R11, 20 |
| 8 | 1 | | 81349 | RCR07G510JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R14 |
| 9 | 1 | | 81349 | RCR07G101JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R25 |
| 10 | 1 | | 81349 | RCR05G121JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R50 |
| 11 | 1 | | 81349 | RCR07G151JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R23 |
| 12 | 6 | | 81349 | RCR07G181JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R52 to R57 |
| 13 | 2 | | 81349 | RCR07G241JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R1, R5 |
| 14 | 1 | | 81349 | RCR07G361JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R21 |
| 15 | 5 | | 81349 | RCR07G621JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R3, 4, 7, 8, 35 |
| 16 | 1 | | 81349 | RCR07G751JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R39 |
| 17 | 2 | | 81349 | RCR07G102JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R13, 15 |
| 18 | 3 | | 81349 | RCR07G152JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R2, 9, 24 |
| 19 | 1 | | 81349 | RCR07G222JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R37 |
| 20 | 1 | | 81349 | RCR07G272JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R22 |

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PARTS LIST CKTCDASSY-RCVR PL06-1371759-1 PL REV --

ASSEMBLY PART NUMBER 06-1371759-1

| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
|---|---|---|---|---|---|---|---|
| 21 | 1 | | 81349 | RCR07G302JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R36 |
| 22 | 1 | | 81349 | RCR07G392JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R38 |
| 23 | 1 | | 81349 | RCR05G472JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R43 |
| 24 | 2 | | 81349 | RCR07G512JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R12,30 |
| 25 | 5 | | 81349 | RCR07G103JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R2, 6, 18, 19, 40 |
| 26 | 1 | | 81349 | RCR07G133JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R31 |
| 27 | 1 | | 81349 | RCR07G203JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R32 |
| 28 | 2 | | 81349 | RCR07G273JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R16,17 |
| 29 | 2 | | 81349 | RCR05G513JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R48, 49 |
| 30 | 6 | | 81349 | RCR07G105JS | MIL-R-39008/1 | RES.,FXD,CMPSN | R26, 27, 28, 29, 33, 34 |
| 31 | 23 | | 81349 | CK05BX103K | MIL-C-11015/18 | CAP.,FIXED,CER | C9, 11, 13, 14, 15, 16, 18, 20, 21, 22, 23, 24, 26, 28, 29, 32, 33, 34, 35, 38, 44, 47, 50, 54 |
| 32 | 9 | | 81349 | CK05BX104K | MIL-C-11015/18 | CAP.,FIXED,CER | C2, 5, 7, 37, 40, 41, 43, 46, 48, 49, 52 |
| 33 | 7 | | 81349 | CK06BX474K | MIL-C-11015/19 | CAP.,FIXED,CER | C1, 4, 17, 19, 25, 27, 51 |
| 34 | 4 | | 81349 | CK06BX105K | MIL-C-11015/19 | CAP.,FIXED,CER | C10, 12, 30, 31 |

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| PARTS LIST | | | | CKTCDASSY-RCVR | PL06-1371759-1 | | PL REV -- |
|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371759-1 | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
| 35 | 2 | | | 196D106X9020JA1 | | CAP, ELEC | C36, 53 |
| 36 | 2 | | 04655 | 50-588439-1 | | CORE | L2, L3 |
| 37 | 8 | | 04655 | 50-588448-1 | | CHOKE | L1, 4, 5, 6, 7, 8, 9, 10 |
| 38 | 1 | | 04655 | 13-588440-1 (1N6280) | | DIODE | CR3 |
| 39 | 2 | | 04655 | 13-588441-1 (1N6267) | | DIODE | CR1, CR2 |
| 40 | REF | | | OPEN | | FOR FUTURE USE | |
| 41 | 6 | | 81349 | JAN1N914 | MIL-S-19500/116 | SEMICON DEV,DIO | CR5, 6, 7, 8, 9, 10 |
| 42 | 1 | | 04655 | 13-588444-1 | NE21889 | TRANSISTOR | Q1, |
| 43 | 1 | | 04655 | 13-588443-1 | NE88935 | TRANSISTOR | Q2 |
| 44 | 1 | | 04655 | 13-588445-1 | NE21935 | TRANSISTOR | Q3 |
| 45 | 1 | | 04655 | 13-588442-1 | HRD 200F | DIODE | CR4 |
| 46 | 1 | | 04655 | 84-588446-1 | | RF SHIELD BOX | |
| 47 | 1 | | 81349 | M39003/01-2301 | MIL-C-39003/1 | CAP.,FXD,ELCTLT | C39 |
| 48 | 4 | | 04655 | 13-588449-1 | 2N3904 | TRANSISTOR, NPN | Q4, 5, 6 |
| 49 | REF | | | OPEN | | FOR FUTURE USE | |
| 50 | REF | | | DELETE | | DELETED ITEM | |
| 51 | 3 | | 81349 | M39003/01-2374 | MIL-C-39003/1 | CAP.,FXD,ELCTLT | C3, C6, C8 |
| 52 | 1 | | 81349 | RCR05G223JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R51 |
| 53 | 3 | | 81349 | RCR05G510JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R41, 44, 45 |

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| PARTS LIST | | | CKTCDASSY-RCVR | | PL06-1371759-1 | | PL REV -- |
|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371759-1 | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | SPECIFICATION | NOMENCLATURE OR DESCRIPTION | NOTE NO. |
| 54 | 1 | | 81349 | RCR05G152JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R46 |
| 55 | 1 | | 81349 | RCR05G102JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R47 |
| 56 | 1 | | 81349 | RCR05G241JS | MIL-R-39008/4 | RES.,FXD,CMPSN | R42 |
| 57 | 2 | | 04655 | 43-588447-1 | | CAPACITOR | C42, C45 |

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| PARTS LIST | | | | CKTCDASSY-XMTR | | PL06-1371757-1 | PL REV -- | |
|---|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371757-1 | | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | MANUFACTURE | NOMENCLATURE OR DESCRIPTION | NOTE NO. | DESIGNATION |
| 1 | | | | BB82C5 | Allen-Bradley | 82 ohm 1/8 W resistor | | R1 |
| 2 | | | | BB1015 | Allen-Bradley | 100 ohm 1/8 W resistor | | R2-R5 |
| 3 | | | | BB1515 | Allen-Bradley | 150 ohm 1/8 W resistor | | R6 |
| 4 | | | | BB2015 | Allen-Bradley | 200 ohm 1/8 W resistor | | R7 |
| 5 | | | | BB2715 | Allen-Bradley | 270 ohm 1/8 W resistor | | R8 |
| 6 | | | | BB3915 | Allen-Bradley | 390 ohm 1/8 W resistor | | R9 |
| 7 | | | | BB5115 | Allen-Bradley | 510 ohm 1/8 W resistor | | R10, R11 |
| 8 | | | | BB7515 | Allen-Bradley | 750 ohm 1/8 W resistor | | R12 |
| 9 | | | | BB1025 | Allen-Bradley | 1K ohm 1/8 W | | R13-R17 |
| 10 | | | | BB1225 | Allen-Bradley | 1.2K ohm 1/8 W resistor | | R18, R55 |
| 11 | | | | BB2025 | Allen-Bradley | 2K ohm 1/8 W resistor | | R19 |
| 12 | | | | BB3025 | Allen-Bradley | 3K ohm 1/8 W resistor | | R20, R21 |
| 13 | | | | BB5125 | Allen-Bradley | 5.1K ohm 1/8 W resistor | | R22 |
| 14 | | | | BB1035 | Allen-Bradley | 10K ohm 1/8 W resistor | | R23-R25, R28 |

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| PARTS LIST | | | | CKTCDASSY-XMTR | | PL06-1371757-1 | PL REV -- | |
|---|---|---|---|---|---|---|---|---|
| ASSEMBLY PART NUMBER 06-1371757-1 | | | | | | | | |
| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | MANUFACTURE | NOMENCLATURE OR DESCRIPTION | NOTE NO. | DESIGNATION |
| 15 | | | | BB8235 | Allen-Bradley | 82K ohm 1/8 W resistor | | R26, R27 |
| 16 | | | | BB1055 | Allen-Bradley | 1M ohm 1/8 W resistor | | R29, R30 |
| 17 | | | | EB1005 | Allen-Bradley | 10 ohm 1/2 W resistor 2% | | R31 |
| 18 | | | | L04D1.00R | Corning | 1 ohm precision resistor 2% | | R32, R33 |
| 19 | | | | RLR05C10R0GR | Corning | 10 ohm precision resistor 2% | | R34, R35 |
| 20 | | | | RLR05C1301GR | Corning | 1.3K ohm precision resistor 2% | | R36 |
| 21 | | | | RLR05C1002GR | Corning | 10K ohm precision resistor 2% | | R37-R40 |
| 22 | | | | RLR05C3302GR | Corning | 33K ohm precision resistor 2% | | R41 |
| 23 | | | | RLR05C5102GR | Corning | 51K ohm preciion resistor 2% | | R42, R43 |
| 24 | | | | RLR05C1003GR | Corning | 100K ohm precision resistor 2% | | R44, R45 |
| 25 | | | | RN55D2004F | Allen-Bradley | 2M ohm precision resistor 1% | | R46-R48 |
| 26 | | | | BW-20 | TRW | .22 ohm 1 W resistor | | R49 |
| 27 | | | | 66WR200 | Beckman | 200 ohm 1/2 W cermet trimpot | | R50 |
| 28 | | | | 66WR10K | Beckkman | 20K ohm 1/2 W cermet trimpot | | R51 |

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PARTS LIST CKTCDASSY-XMTR PL06-1371757-1 PL REV --

ASSEMBLY PART NUMBER 06-1371757-1

| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | MANUFACTURE | NOMENCLATURE OR DESCRIPTION | NOTE NO. | DESIGNATION |
|---|---|---|---|---|---|---|---|---|
| 29 | | | | 66WR1M | Beckman | 1 M ohm 1/2 W cermet trimpot | | R52 |
| 30 | | | | 66WR2M | Beckman | 2 M ohm 1/2 W cermet trimpot | | R53 |
| 31 | | | | 3250W-1-200 | Bourns | 20 ohm 1 W cermet trimpot | | R54 |
| 32 | | | | TBD | Lasertron | TBD | | Laser Pkg. |
| 33 | | | | BB3025 | Allen-Bradley | 3K ohm 1/8W resistor | | R56 |
| 34 | | | | BB1055 | Allen-Bradley | 1M ohm 1/8 W resistor | | R57 |
| 35 | | | | BB1035 | Allen-Bradley | 10K ohm 1/8 W resistor | | R58-R60 |
| 36 | | | | 503D108F010PE | Sprague | 1 mf electrolytic capacitor 10V | | C1 |
| 37 | | | | 5FA201J | Arco | 200 pf Mylar capacitor | | C2 |
| 38 | | | | 8121-100X7RC10 | Erie | 0.001 μf ceramic capacitor 100V | | C3-C5 |
| 39 | | | | 503D106F035LA | Sprague | 10 μf electrolytic capacitor 35V | | C6, C7 |
| 40 | | | | 2CZ50474X0500 | Sprague | 0.47 μf electrolytic capacitor 50V | | C8-C26 |
| 41 | | | | 8121-100X7R022 | Erie | 0.0022 μf 100V | | C27 |
| 42 | | | | CSR-13C227KL | Sprague | 220 μf 10V | | C28 |
| 43 | | | | 503D157F016NC | Sprague | 150 μf 16V | | C29 |
| 44 | | | | 1N914 | ------- | Diode | | D1-D5 |

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PARTS LIST CKTCDASSY-XMTR PL06-1371757-1 PL REV --

ASSEMBLY PART NUMBER 06-1371757-1

| FIND NO | QTY REQD | UNIT MEAS | FSCM | PART OR IDENTIFYING NO. | MANUFACTURE | NOMENCLATURE OR DESCRIPTION | NOTE NO. | DESIGNATION |
|---|---|---|---|---|---|---|---|---|
| 45 | | | | 5082-2835 | H-P | Diode | | D6 |
| 46 | | | | IN5908 | Gen. Semi. Inc. | Transzorb | | D7-D8 |
| 47 | | | | LM113 | Natl. Semi. | Zener Diode | | D9, D10 |
| 48 | | | | 1N5823 | Motorola | Diode | | D11 |
| 49 | | | | 1N914 | -------- | Diode | | D12-D14 |
| 50 | | | | CA3130T | RCA | Operational Amplifier | | U1, U2 |
| 51 | | | | OP-07 | PMI | Operational Amplifier | | U3 |
| 52 | | | | LM3302n | Natl. Semi. | Comparator | | U4 |
| 53 | | | | UA78S40 | Fairchild | Switching Regulator | | U5 |
| 54 | | | | A406 | Amperex | Transistor, RF | | Q1, Q2 |
| 55 | | | | 2N3904 | ------- | Transistor, Signal | | Q3, Q4 |
| 56 | | | | 2N3906 | ------- | Transistor, Signal | | Q5 |
| 57 | | | | ECG188 | Sylvania | Transistor, Power | | Q6 |
| 58 | | | | W172 DIP-5 | Magnecraft | Relay | | K1 |
| 59 | | | | 104-20-B | Ferronics Inc. | Choke, form | | L1, L2 |
| 60 | | | | VK20010/3B | Ferrox Cube | Choke, Power | | L3-L6 |
| 61 | | | | F1146-1-TC9-4 | Indiana Gen. | Pot Core | NOTE 1 | L7 |
| 62 | | | | B475-1 | Indiana Gen. | 265 μH Inductor Bobbin | NOTE 1 | L7 |
| 63 | | | | B659 | Indiana Gen. | Bracket | NOTE 1 | L7 |

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NOTE 1: 26 turns no. 22 enamel wire.

## APPENDIX B

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